

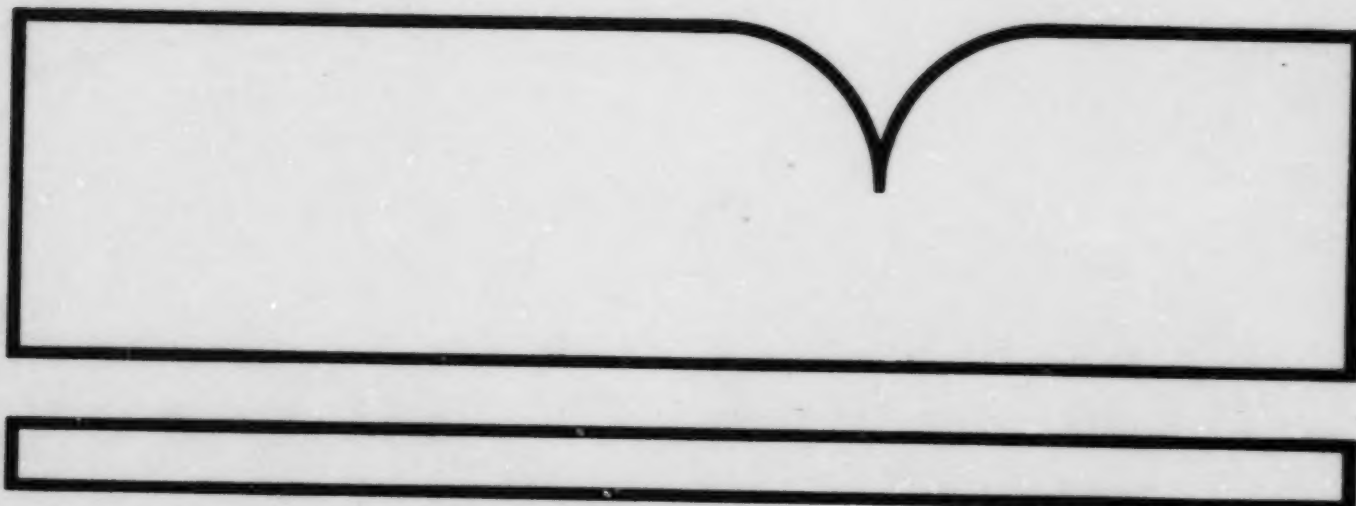
Evaluation of 19 On-Site Waste Treatment
Systems in Southeastern Kentucky

Parrott, Ely, and Hurt
Lexington, KY

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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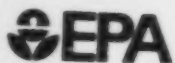


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Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-80-101
July 1980

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Evaluation of 19 On-Site Waste Treatment Systems in Southeastern Kentucky

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EPA-600/2-80-101
July 1980

EVALUATION OF 19 ON-SITE WASTE TREATMENT
SYSTEMS IN SOUTHEASTERN KENTUCKY

by

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Contract No. CA-8-2575-A

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16. ABSTRACT This report provides a summary of the design, installation, operation and maintenance, performance, and costs of nineteen prototype on-site systems originally installed in 1970-1972 by the Appalachian Environmental Health Demonstration Project. These systems included electric and gas-fired incinerating toilets, recycling toilets, extended aeration units followed by open sand filters, septic tanks followed by horizontal sand filters, and septic tanks followed by soil absorption trenches. Of the 6 basic types of systems evaluated in this study, the septic tank soil absorption systems were found to have the lowest cost and highest level of performance.		
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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

In many rural areas of the country, low density development, adverse topographical conditions, and limited economic base may prohibit installation of conventional sewers and centralized wastewater treatment. In such cases, alternative wastewater handling techniques must be considered. One objective of the Appalachian Health Demonstration Project was to provide techniques for the safe and sanitary disposal of human wastes. This was accomplished through the construction of several different types of on-site wastewater treatment systems in Southeastern Kentucky. This report summarizes the design, installation, operation and maintenance performance, and costs for these systems, which were monitored over a 2-year period.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

In 1970, many of the homes in rural Southeastern Kentucky were lacking adequate sanitary facilities for the disposal of human wastes. Shallow soils, steep slopes, and high groundwater levels made it difficult to provide sanitary wastewater disposal systems at a reasonable cost. Forty to sixty percent of the households had annual incomes of less than \$3,000 in 1969. The median value of owner-occupied housing units in this area in 1970 was under \$7,000, compared to the national median value of \$17,000.

The Appalachian Environmental Health Demonstration Project (AEHDP), funded by the Appalachian Regional Commission in 1968, concerned itself with sewage disposal as one of several program areas. Twenty "prototype" on-site treatment systems were constructed to handle human body wastes (blackwater) generated within the home. These systems included electric and gas-fired incinerating toilets, recycling toilets, extended aeration units followed by open sand filters, septic tanks followed by open sand filters, septic tanks followed by horizontal sand filters, and septic tanks followed by soil absorption trenches.

In 1978, the U.S. Environmental Protection Agency awarded a contract to Parrott, Ely, and Hurt of Lexington, Kentucky to summarize the AEHDP effort, gather existing data on the operation, maintenance, performance, and costs of the installed systems, and to inspect each system, collecting new data where appropriate and feasible.

This report provides a summary of the design, installation, operation and maintenance, performance, and costs of nineteen prototype on-site systems installed in 1970-1972. In addition, the alternatives are evaluated against a set of criteria which includes user acceptance, health protection, safety, energy requirements, longevity, frequency of maintenance, and capital and operation/maintenance costs.

This report was submitted in fulfillment of Contract No. CA-8-2575-A Parrott, Ely, and Hurt Consulting Engineers under the sponsorship of the U.S. Environmental Protection Agency. The recent data collection efforts and report preparation covered a period from February 17, 1978 to July 26, 1978. However, the on-site wastewater systems described in the report were installed and monitored between 1970 and 1973 under the sponsorship of the Appalachian Health Demonstration Project.

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Mr. James W. Carpenter, Jr., formerly Director of the Appalachian Environmental Health Demonstration Project, provided files and other materials pertaining to the project. Mr. Wilburn C. Jackson, formerly with the sewage disposal program of the project, provided valuable assistance in locating several of the systems and in describing the actual construction of the subsurface systems. Mr. E. Bayne Blankenship, PhD., of Research Products/Blankenship, Dallas, Texas, provided detailed information and specifications on the electrical incinerating toilets. Mr. Michael F. Martin, of LaMere Industries, Walworth, Wisconsin, provided information and specifications on the gas-fired incinerating toilet.

SECTION 1

INTRODUCTION

The need for improved designs of home sewage disposal systems is as great in Appalachian Kentucky as in most other mountainous areas. Shallow soils, steep slopes and high groundwater levels are frequently encountered. Equally important are economic constraints. In Southeastern Kentucky counties, 40 to 60 percent of the households had annual incomes of less than \$3000 in 1969. The total net assessed valuation of real, tangible and intangible properties averaged \$2900 per capita in 1970. The median value of owner occupied housing units in 1970 was less than \$7000, as compared with \$17,000 for the United States. Less than 10% of the population lived in urban centers.

These factors clearly demonstrated the need for alternative means for wastewater management. The Appalachian Environmental Health Demonstration Project (AEHDP) was funded by the Appalachian Regional Commission (ARC) in September 1968, with sewage disposal as one of several program areas.

Although the first emphasis of the Project was to expand sewer systems, a provision was made in a 1968 budget revision to include construction of several "prototype" home sewage disposal systems. By 1971, 20 prototype systems had been installed. The remainder of this report describes the design, construction and evaluation of 19 of these prototype systems.

Since this report evaluates actual operating on-site systems in rural Kentucky, the volume of waste generated by the residents is highly variable. Therefore standard per capita waste volume was not used in reporting actual loadings on the systems. The waste volume generated by each residence depended on the actual site, lifestyle of the residents, and the type of on-site unit used at a particular location.

SECTION 2

SUMMARY AND CONCLUSIONS

The systems installed in the AEHDP on-site disposal program in 1970 and 1971 were designed as "blackwater" or human excrement waste treatment systems. In all 19 cases studied, a simple outdoor privy had been in use before the prototype system was installed.

In some cases the "prototype" system was discarded in less than 2 years, the outdoor privy being preferred by the owners. Five of the incinerating toilets and the two recycling systems had been removed or converted to more conventional systems within 4 years. One of the gas incinerating toilets had exploded while in use.

The systems which utilized a standard flush toilet and simple treatment with discharge to the soil or surface stream were still operable in 1978. Eight of these systems were in active use, while 3 were at vacant homes. The two extended aeration systems had suffered breakdowns and were operating anaerobically in 1978.

Both small, semi-open, sand filters and subsurface sand filters were operating adequately in 1978. The subsurface "horizontal" sand filters were of non-conventional design and were operating without a visible effluent.

The four septic tank-soil absorption systems which were still in use in 1978 were performing adequately. Even the system which had been converted from a recycling system to a septic tank-soil absorption system worked well. The latter system was installed in a filled-in front yard about 37 m² (400 square feet) in area.

The projected operating - maintenance costs for the incinerating and recycling systems were very high, ranging from \$23 to \$39 per month. The projected total annual costs for these systems in 1978 would be \$426 for a gas incinerating toilet, \$541 for an electric incinerating toilet and \$641 for a recycling toilet. Performance of these systems varied widely, ranging from ratings of "unacceptable" to "very good" in 7 selected categories. The incinerating units required unacceptably high energy consumption for use by the target population, and in general performed poorly. The recycling systems appeared to require high levels of maintenance to achieve nuisance-free operation. The primary advantage of the recycling and incinerating systems was the freedom from soil requirements.

The extended aeration-open sand filter (EA-OSF) systems operated in the aeration mode for about 7 years. Both aerators ceased operation in 1978, from different causes. With proper repair, both could be put into operation again. One tank was operating acceptably as a two-compartment septic tank

in 1978. The effluent from the open sand filter was very high in nitrate nitrogen, with levels ranging from 220 to over 600 mg/L. Fecal coliform counts were zero on two days and 700 per 100 ml another day. Other effluent parameters were acceptable for the local conditions. Projected costs for an EA-OSF system in 1978 were moderately high. Annual O & M was about \$180, while total annual costs were estimated to equal \$336.

One septic tank-open sand filter (ST-OSF) system was operating but needed maintenance in 1978. The house on the other ST-OSF system was vacant, but the system had operated without any maintenance for 6 years. The effluent from the ST-OSF system was acceptable for local conditions except for fecal coliform levels. Fecal coliform counts ranged from 13,000 to 100,000 per 100 ml. Projected costs for a system in 1978 indicated an annual O & M of \$24 and a total annual cost of \$123.

Two of the three septic tank-horizontal filters were operating successfully in 1978; the other system was on a house which had been vacant for less than a year. Performance of these systems was good. No effluent had ever been detected from these subsurface filters. Based on measurements of ponding and rates of filter loadings, the horizontal filters have a projected useful life of over 30 years. These filter systems have fairly unrestrictive site requirements and very low O & M costs. Average annual O & M was projected at \$9, and total annual costs were projected to equal \$107 for a family of three persons.

Of the 6 basic types of systems evaluated in this study, the septic tank-soil absorption (ST-SA) systems were found to have the lowest cost and highest level of performance. Where suitable soils are located or can be economically imported, ST-SA would be the preferred system. Study of the prototype systems and other experience has shown that with proper design and installation, many sites which would often be considered unsuitable for soil absorption can be utilized successfully. The ST-SA systems were projected to have an annual O & M cost of \$9 and a total annual cost of \$63 for a family of 3 persons.

SECTION 3

BACKGROUND

Sixteen Southeastern Kentucky counties had fairly unique opportunities for environmental health improvements due to the formation of the Appalachian Environmental Health Demonstration Project (AEHDP) of the Kentucky State Department of Health. The Project encouraged innovation in upgrading environmental health services as a primary mission.

An early concept developed in the AEHDP was to develop a broad range of system designs for home sewage disposal at existing homes. More than 200,000 persons (80% of the population) in the AEHDP area used on-site disposal. Little prospect was seen for conventional sewers in most areas.

The most common mode of on-site disposal was the outdoor privy. Some were merely wooden stalls perched over a stream bed. Others were built over pits, but without benefits of insect screening and proper ventilation. In counties without a plumbing code, flush toilets sometimes discharged directly to a streambank. Some septic-tank effluent was discharged to the streams. Where the plumbing code was enforced, an attempt was made to provide subsurface absorption of effluent. However, the code contained no provision for slope, groundwater levels, soil depth below absorption surfaces or other significant soil factors.

A survey of AEHDP County Health Departments in 1972 revealed that nearly 2000 septic tank and 50 extended aeration installation permits were issued annually. Only two of the Departments had conducted any surveys of private sewage disposal systems.

The Kentucky Plumbing Code requirements for septic tank - soil absorption system were minimal. Tanks had to have a minimum capacity of 1.89 m^3 (500 gallons) and could be located no nearer than 3.05 m (10 feet) to property lines or 15.2 m (50 feet) to wells or cisterns. Absorption trenches were not to be closer than 6.1 m (20 feet) to a building, 1.5 m (5 feet) to a property line and 21.4 m (70 feet) to a water supply well or cistern. Minimum absorption system area was 37.2 m^2 (400 square feet), provided in 61 m (200 lineal feet) of trench 0.6 m (2 feet) wide. The combined effect of these requirements dictated that a nearly level area with dimensions of at least 18 m by 17 m (60 feet by 57 feet) was required. The lack of consideration of groundwater, soils and geologic conditions contributed to a lack of success with subsurface absorption in many areas. No alternative systems were recognized by the Code.

A local housing improvement project helped focus attention on the inadequacies of the Code. This project, known as the Letcher-Knott-Leslie-Perry (LKLP) home repair project, was conducted by the Eastern Kentucky Housing Development Corporation (EKHDC). Grants of \$500 were obtained from the

Social and Rehabilitation Service for eligible persons, and loans of up to \$1,500 were obtained from Farmers Home Administration. The LKLP project found that over 60 percent of their clients indicated bathroom facilities as either first or second priority for home improvement. Attempts to provide bathroom facilities were often frustrated by a lack of suitable area or other site conditions needed for subsurface disposal under the code, as interpreted by local inspectors.

The EKHDC and AEHDP personnel discussed these problems, and AEHDP agreed to provide alternative systems designs, supervision of installations and funds for capital expenditures on selected home sites. The criteria for site selection included the provision that the home site was not suited for the system specified in the Plumbing Code. The homeowner was required to sign an agreement with AEHDP permitting access to the system for testing over a two-year period. He was also required to sign a release waiving the right to sue the AEHDP in case of system failure. Manpower and equipment required for construction was provided by the EKHDC. Other personnel were provided by Operation Mainstream and the Concentrated Employment programs.

While AEHDP could propose system designs, no authority had been delegated for internal approval of designs. Each system was subjected to multiple reviews by State personnel in Frankfort. The State Plumbing Program reviewed all alternative designs and none could be installed without their approval. Any design having a surface discharge also was reviewed by the Water Pollution Control program, which could disapprove any design. Due to the shortage of qualified personnel and the low priority of the individual systems, reviews sometimes required months to complete. The last design which was submitted, an evaporation-filtration mound, was unapproved at the termination of the AEHDP approximately 14 months after submittal.

It was decided early in the project to eliminate consideration of "gray water", those wastewaters generated from all fixtures except the toilet. This automatically lessened the design problem in regards to volume, and concentrated efforts on the "black wastes", human feces and urine. While it was recognized that gray water may contain residual feces and urine (and associated pathogens), the decision was made (on the basis of comparative health risk to the present unhealthful conditions) to deal with black wastes only.

A literature review was conducted over a period of several weeks. The libraries at the University of Kentucky were utilized in this review. No comprehensive bibliography for on-site disposal was available to the researchers. The literature search and analysis permitted the selection of four areas for further investigation. These were:

- (1) Reduction in volume;
- (2) Reduction in organic load;
- (3) Improved methods for effluent absorption in soil;

(4) Proprietary or site-constructed treatment devices.

One staff member of AEHDP was assigned primary responsibility for the prototype sewage disposal program. During the course of the 5-year project period, 3 individuals were assigned this responsibility at various times. Other staff members contributed to design concepts and monitoring of system performance.

While the potential existed for installation of 100 to 200 "prototype" systems under various combinations of site conditions, the many constraints placed on the program reduced this number to only 20. These constraints included the client eligibility requirements, the drawnout review process, the reluctance of review agencies to approve innovative systems, the changes in AEHDP personnel, the lack of experience in assigned personnel, the difficulties in coordination between EKHDC, AEHDP and other State programs, and the low priority placed on this program by AEHDP and other State programs.

In this present (1978) evaluation study, the systems were visited in the field for observation, testing and user interviews. Available files retained by former AEHDP personnel were reviewed and analyzed. It was found that records had been lost on one system, and that system could not be located. Therefore only 19 systems have been evaluated. The location of these 19 systems is shown on Figure 1. The letter-number designation used in Figure 1 correlates with Table 1.

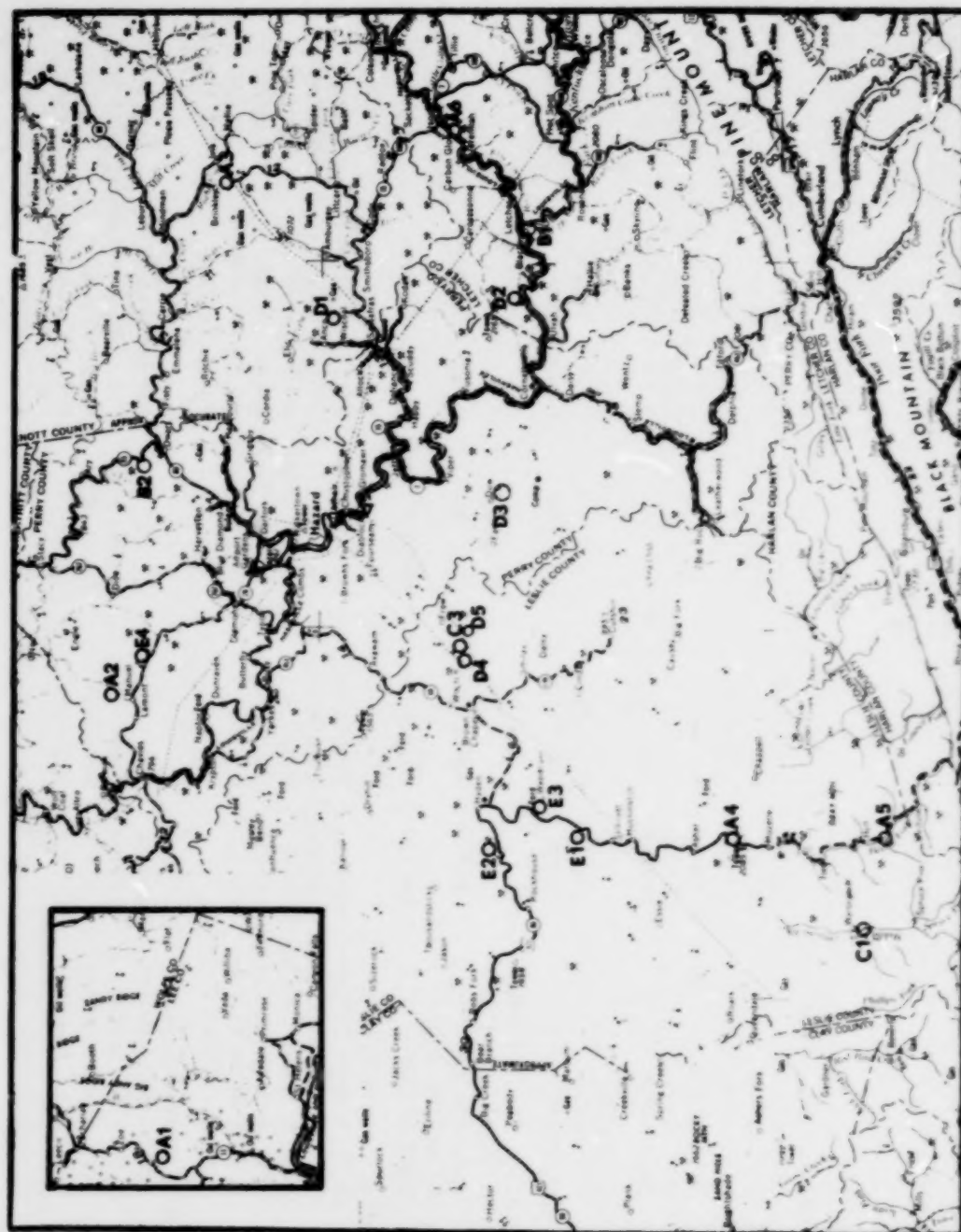


Figure 1. Location of on-site waste disposal systems in southeastern Kentucky.

TABLE NO. 1
APPALACHIAN ON-SITE DISPOSAL SYSTEMS
SUMMARY OF RECONNAISSANCE SURVEY
MAY, 1978

TYPE SYSTEM	LOCATION			CURRENT OWNER OR CONTACT	CURRENT USE
	COUNTY	COMMUNITY (from Quad)	ROAD/CREEK		
A. Incinerating Toilet					
1. Incinoleet	Lee	Zachariah	Ky 11	Ky. River G.R.D.D.	Abandoned
2. Incinoleet	Perry	Manuel	Trace Br.	Willie Watts	Abandoned
3. Destroilet	Knott	Brinkley	Ky 160	Hester Smith	Abandoned
4. Destroilet	Leslie	Asher	US 421	Roy Ward	Abandoned
5. Destroilet	Leslie	Helton	S 421	Gorman Wilson	Vacant
6. Destroilet	Letcher	Jeremiah	Ky 7	John M. Blair	Abandoned
B. Recycling Toilet					
1. Uniroyal	Letcher	Blackey	Ky 7	Jessie Gibson	Converted
2. Uniroyal	Perry	Dwarf	Mill Br.	Dewey Combs	Abandoned
C. Aeration and Filter					
1. Allenaire and sand filter	Leslie	Warbranch	Middle Fort Ky.	B & W. Caldwell	Active
2. Allenaire and sand filter	Leslie	Wooton	Second Fork	Henry Kilburn	Active
D. Septic Tank & Filter					
1. S.T. & open filter	Knott	Sassafras	Ky 1089	Martin Hall	Active
2. S.T. & trench filter	Letcher	Ulvah	Ky 7	Ellen Fields	Active
3. S.T. & trench filter	Perry	Viper	Maces Creek	Mary Joseph	Active
4. S.T. & trench filter	Leslie	Wooton	Second Fork	Roger Turner	Vacant
5. S.T. & open filter	Leslie	Wooton	Second Fork	Nancy Pennington	Vacant
6. S.T. & filter				Kelly Turner	Not Found
E. Septic Tank & Soil					
1. S.T. & rec. trench	Leslie	Stinnett	US 421	Farmer Howard	Active
2. S.T. & v. trench	Leslie	Hyden	Jason's Br.	Mrs. Chester Lawson	Active
3. S.T. & rec. trench	Leslie	Wendover	Wend. Rd.	Hayes Morgan	Active
4. S.T. & v. trench	Perry	Grapevine Cr.	Ky 28	Mrs. Jos Whitaker	Vacant

SECTION 4

SYSTEM DESCRIPTIONS

GENERAL DESCRIPTION AND STATUS

A total of 20 systems were installed in the years 1970-1972 under the supervision of AEHDP. These included 6 incinerating toilets, two recycling systems, two aeration-filtration treatment systems, 6 septic tanks with sand filtration systems and 4 septic-tanks with soil absorption systems. One of the systems utilizing a septic-tank and sand filter could not be located during this study. Table 1 contains a listing of the systems with locations, owners names and current use status. Figure 1 shows locations on a US Series map. Use status was determined in April and May, 1978, and the following brief summary was current as of that period.

All of the incinerating toilets had been either removed or a flush toilet substituted. User dissatisfaction with both the gas and electric models was high. One person was burned and required hospitalization when a gas toilet ignited prematurely in 1974.

One of the recycling toilet systems was dismantled and was not functional. The aeration tank of the other was converted to a septic tank and a soil absorption system added.

Three of the five septic tanks followed by sand filtration (ST-SF) were still in use and had functioned satisfactorily. Two ST-SF systems appeared functional but the houses were vacant.

All of the septic tanks with soil absorption (ST-SA) systems appeared functional, with no surface seepage or malfunction being evident. One of the houses served by a ST-SA had been vacant since 1976. The recycling system which had been converted to a ST-SA system was functioning satisfactorily.

DETAILED DESCRIPTIONS AND COSTS

Electric Incinerating Toilets

Description of the Unit--

The "Incinolet" toilet was an electrically heated model (No. CFIV) manufactured by Research Products Manufacturing Company of Dallas, Texas. No catalyst was installed as is now provided in current models of Incinolet. The units were rated at 2200 watts, 120 VAC. (Current models have ratings of 2800 to 3650 watts.) A manual timer with a maximum 60 minute cycle was installed. These toilets were first marketed in the late 60's.

The basic configuration of this unit is retained in current models, although timer and heater specifications have changed and a catalyst added. Figure 2 illustrates the basic configuration used.

This toilet was force-vented to the outside atmosphere by a cage-type blower which ran simultaneously with the timer switch. The use cycle was begun with placement of a waxed paper bowl liner on the upper surface of the flushing bowl. After depositing waste, the user would push down on the foot pedal which opened the bowl, release the pedal after the paper and waste dropped into the lower chamber, and then turn the timer to begin the heating cycle. The manufacturer's literature states that the unit may be used while in the incinerating cycle, but the users in Kentucky were reluctant to do so.

Installation requirements were fairly simple. The toilet was bolted to the existing floor. Electrical service was run from a separate fuse box and the unit grounded by an individual ground wire. A hole was cut in the adjacent wall and a 4" diameter vent pipe was extended to an elevation above the roof. The dimensions of the unit were approximately 580 mm x 380 mm x 530 mm (23 inches by 15 inches by 21 inches).

Construction Costs--

Initial costs for purchase of the toilet, installation, electrical service and venting totaled about \$600. The toilet cost in 1970 was about \$500.

Operating Costs--

Operating costs were primarily related to electrical consumption. Waxed paper bowl liners had a cost of approximately 0.2 cents each in 1970, or about 40 cents per person per month. At a rate of 1.5 cents per kilowatt-hour, the electrical service cost totaled about \$3.00 per month in a household having 3 people. Current manufacturer's literature states that one kilowatt-hour of electricity is consumed per use cycle. This would equal about 210 kilowatt-hours per person per month, if each resident did not use facilities at other locations and used the unit 7 times per day. Current electrical rates of 4¢/KWH would produce costs of about \$25 per month with full-time use by three persons.

Maintenance Costs--

Maintenance was provided for these toilets by AEHDP until August, 1973. One unit was under AEHDP maintenance for a period of about 2½ years. The other was installed at a home for about 6 months, then removed and placed in a landfill site office. Records kept by AEHDP show that the electric toilets required about 3 visits per year per unit for service and repairs. Total repair time was 3.5 hours per year, plus travel. Parts costs were low, consisting of new wiring and fuses. Details of repairs are listed in Appendix A.

Assuming one hour of travel per visit, a service rate of \$10 per hour and 20 miles of travel at 12¢ per mile, total annual maintenance costs would be about \$67.

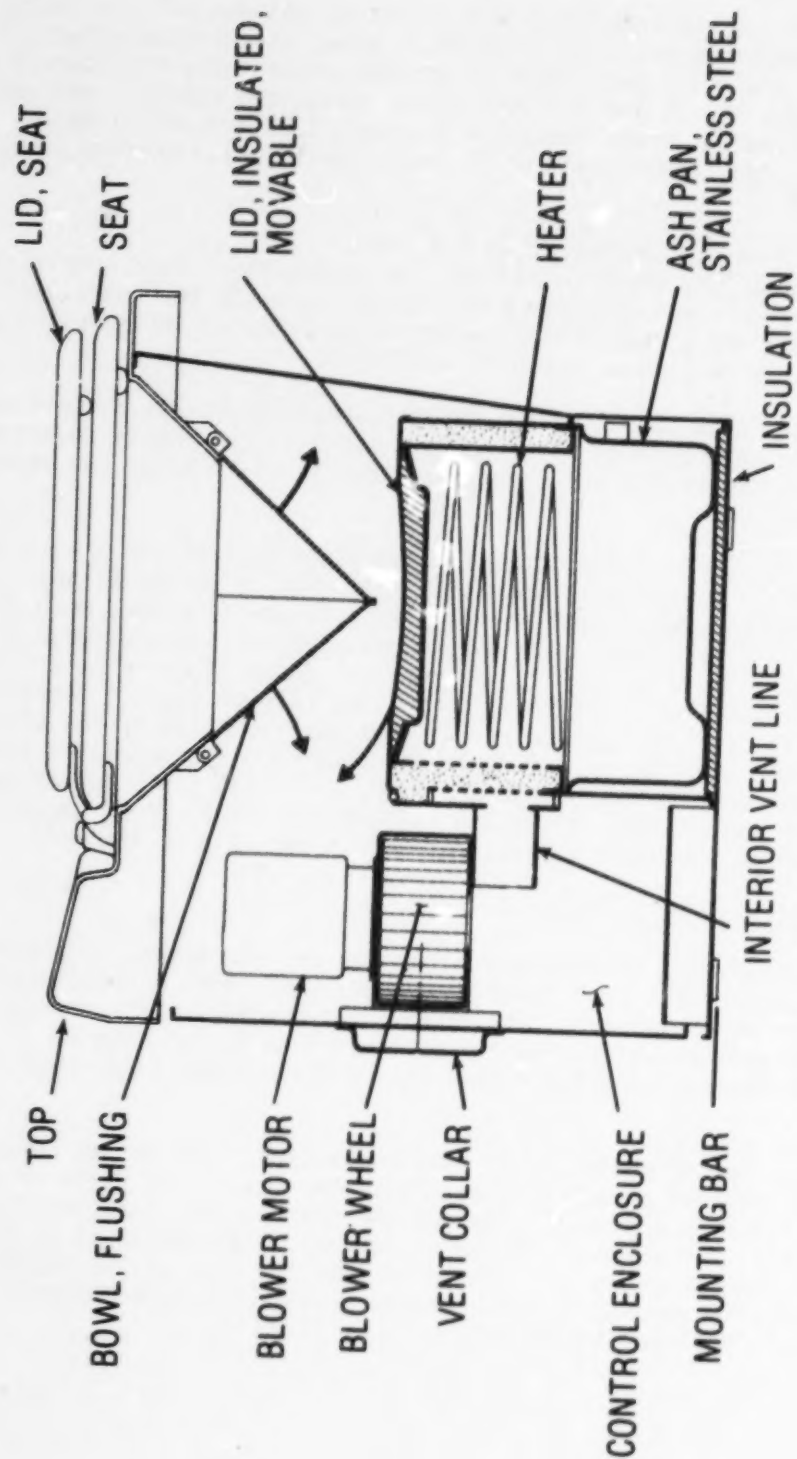


Figure 2. Electric incinerating toilet configuration.

Life-Cycle Costs--

The construction of and experience with electric toilets in this project would indicate a probable useful life of about 7 years, assuming acceptable levels of performance and daily use. With an assumed present-day replacement cost of \$850, interest at 10% and a 7 year life, annualized capital cost would equal \$174. Added to annual operation of about \$300 and annual maintenance costs of \$67, total annual costs would equal \$541. Total monthly costs would equal about \$45.

Performance of Electric Incinerating Toilets--

The performance of the electric toilets was inadequate. User complaints centered on the unit not completely oxidizing the waste to "inert ash". Users were forced to scrape partly burned feces from the incineration chamber. Operating costs were also a source of complaint.

At one home, the user complained repeatedly about the operating cost and finally had the unit removed after about 6 months. The family reverted to using their outdoor privy, which they had kept in place after the electric toilet was installed.

The second Incinolet (A-2) was installed in January, 1971, at a home having three residents. It was retained until early 1974, a period of about three years. The users reported that wastes were only partly burned much of the time. Use during this period was only occasional, with the outdoor privy being preferred. This family did not complain about higher electric bills, which probably were little affected by the low rate of use. A conventional septic-tank with soil absorption of effluent was installed by the owner in 1974. The owner reported no difficulty in obtaining the necessary permit. The cost of the septic-tank system was \$700. When the flush toilet was installed, the incinerator toilet was removed and stored in an outbuilding. As of July, 1978, the owner had no plans for future use of the unit.

Gas-fired Incinerating Toilets

Gas-fired incinerating toilets were installed at four homes. One was Destroilet Model 52 P5B, and three were model L15B, both manufactured by LaMere Industries of Walworth, Wisconsin. The manufacturer's representative reported that similar toilets have been in service for as long as 20 years. LaMere Industries has reportedly sold 55,000 Destroilets in 41 countries.

Description of the Unit--

The Destroilet was slightly larger than a standard flush toilet bowl. The painted metal cabinet projected about 2½ inches beyond the front of the toilet seat and 5 inches to the rear of the seat hinge. A standard toilet seat was fitted to the top of the metal cabinet. The installed weight was 100 pounds. Exhaust gases were vented through the rear of the cabinet by use of an electrically powered blower. Figure 3 shows the main features of the Destroilet unit employed in the study.

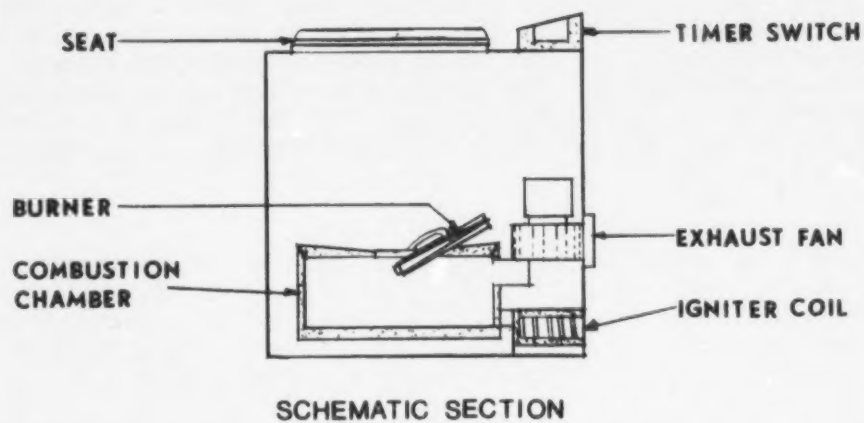


Figure 3. Schematic diagram of gas incinerating toilet.

The manufacturer reported the rated energy input to be 7320 watts (25,000 BTU per hour). About 0.1 Kg. (0.20 lb) of L.P. gas was the design consumption for a typical 15 minute burn cycle. The standard unit is rated for 60 cycles per 24 hours. The unit was reported to be certified by the American Gas Association.

The combustion chamber was constructed of cast iron in Model 52 and of steel in Model L15B. Ignition was accomplished by a spark plug, so no pilot flame was necessary. A sail switch was used to detect proper movement of air in the exhaust pipe.

Operation of Gas-Fired Incinerating Toilet--

The unit was used in a manner similar to a flush toilet. Wastes were deposited directly into the combustion chamber, with no paper liner being required. After depositing waste, the user would close the cover and actuate the combustion-timer mechanism. The exhaust blower and burner operated simultaneously for the 12 to 16 minute burn cycle. The blower would continue to run for six to seven minutes after the flame shut-off; it was rated at $0.066 \text{ m}^3/\text{s}$ (140 CFM).

Installation of Gas-Fired Incinerating Toilet--

Both gas and electrical supplies were required for the Destroilet. Modifications of the burner permitted the use of either natural or liquified petroleum gas. Floor space equal to that required for a standard flush toilet was adequate. All AEHDP installations placed the unit at an outside wall to permit convenient installation of the exhaust pipe.

Installation consisted of bolting the unit to the floor, providing gas and electrical connections and installing the exhaust vent. It was necessary to carefully adjust the air-fuel ratio for efficient combustion of the wet wastes. (The manufacturer reported that Destroilets are normally sold and installed by LP gas dealers.)

Construction Costs--

Initial costs for purchase and installation of the Destroilet were estimated to equal \$450 in 1971. This did not include costs for room additions or modifications. In 1978, a local LP gas and appliance dealer quoted a price of \$580 for the Destroilet plus \$175 for venting.

Operating and Maintenance Costs--

Operating and maintenance costs were made up of gas consumed, labor for maintenance, and repair parts. AEHDP records show an average (per unit) of 3.8 visits per year requiring a total of 7 hours per year in maintenance and repair time. Travel time was not included. The annual cost for parts averaged \$12 per unit. Typical maintenance involved cleaning the spark plug, adjusting spark gap and adjusting the air-fuel ratio. Repairs included correcting leaks in gas lines, replacing timers and replacing blower motors. (See Appendix.) Timers and motors were the highest cost item, at a cost of about \$40 for both. Two units required timer and motor replacement within the two year monitoring period.

There was a wide variation in the number of visits and hours required for maintenance and repair. One unit required three visits totaling 6.5 hours. The most troublesome unit required 15 visits totaling 24 man-hours. The latter unit exploded while in use in 1974, after termination of the AEHDP program.

In contrast to these experiences, the manufacturer reported that units should normally require only one service call per year, for cleaning and lubrication. Such service was reported to be so easy as to be performed by the average homeowner. Evaluation of maintenance records for the units installed by AEHDP indicates that maintenance requirements were considerably greater than those described by the manufacturer.

Average monthly operating costs would consist mostly of gas purchase. The manufacturer reports an average consumption of 0.09 Kg. (0.20 lbs.) of LP gas per cycle. About three cycles are needed to completely consume feces. Assuming an average of 7 cycles per day per user, a three-person family would consume about 1.9 Kg. (4.2 lbs.) of LP gas per day or 57 Kg. (126 lbs.) per month. LP gas was priced at about \$0.12 per liter (46¢ per gal.) in 1978 in Kentucky. The average operating cost per family would be about \$13.70 per month for gas consumed. Electrical consumption by the blower would equal about \$1.50 per month at a rate of 4¢ per kwh.

Total annual O & M costs would include labor for service calls and repair parts. If labor is charged at a rate of \$10 per hour and the average travel distance is 20 miles at 12 cents per mile, maintenance labor would total about \$79 per year. Added to the operating cost of \$182 and parts cost of \$12, total costs for annual operation and maintenance of a Destroilet would equal \$273, based on AEHDP experience.

Life-Cycle Costs

The construction and function of the Destroilet may indicate a useful life of about 5 to 10 years, assuming careful operation and maintenance. The experience of the AEHDP program demonstrated an average useful life of only 3 years. Since the combustion chamber is guaranteed for 5 years, this seems to be a reasonable projection of useful life.

At an assumed replacement cost of \$580 (1978 data), interest at 10% and a 5-year period, the annualized capital cost would equal \$153. Adding the annual operating and maintenance cost of \$273 would result in an annual life-cycle cost of \$426.

Performance of Gas-Fired Incinerating Toilets--

Many of the users reported dissatisfaction with the performance of the Destroilet. Actual records of service calls are included in the Appendix. A summary of user comments is presented in Table 2.

A potential cause of odor in the home was incomplete combustion of feces, which may require three cycles for complete oxidation. In one family there was disagreement on the objectionability of odors.

Mechanical failures were associated with timers, fan motors and burners. The lack of local availability of parts caused excessive down time, requiring an alternative means of human waste disposal.

The most common failure was in the ignition device, which utilized an electrical spark. One unit was removed by the owner due to repeated failure of the ignition system.

TABLE 2 - PERFORMANCE EVALUATION OF GAS INCINERATING TOILETS

Unit	Poor Igni- tion	Incom- plete Combus- tion	Mechan- ical Failure	Odors	Visi- ble Emis- sions	Ex- cess- ive Heat	Ex- plo- sion	Service (Years)
A-3	X	X	X	X	X	X		3
A-4	X		X				X	4
A-5	X	X	X					
A-6	X	X						2

Unit A-3 seemed to have a chronic tendency to accumulate solids as a result of incomplete combustion. No specific cause for this condition was ever determined. Only two elderly persons lived in the home, so overloading was ruled out as a possible cause. This unit also caused objectionable odors in the home and excessive smoke from the exhaust stack. After three years of service, this unit over-heated so much that the exterior paint became dis-colored.

In 1974, the owner of unit A-3 contacted the manufacturer for advice on repairs. He reported that the estimated repair charges were \$300 at that time. The owner decided to install a standard flush toilet and septic tank with soil absorption field. The Destroilet was retained after installation of the septic-tank system and was being utilized as a low table in 1978.

Unit A-4 required more service calls than any other. This unit received regular use by an elderly person who was confined to a wheelchair. The records on type of service performed are shown in Appendix A. It is known that the ignition system was adjusted several times and the blower motor was replaced. A total of 15 service calls were made over a period of about 2½ years.

Unit A-4 exploded while in use in 1974. The explosion caused burns on the user, who required hospitalization. Apparently no one who had been associated with AEHDP was made aware of this accident until 1978. The cause of the explosion is unknown, since the toilet was removed and discarded in 1974 without examination or testing being done. G. Townley (Consultant, Norman,

Oklahoma-personal communication) provided the following information:

"Explosions previously experienced with the Destroilet were due to incomplete combustion of gas when the unit cut off. It is my understanding that this problem was eliminated on-site by drilling holes into the cast iron firing chamber and later by the manufacturer with redesign."

Unit A-5 was installed at two separate homes during the initial study. Occupants of the initial location requested removal of the unit because they were dissatisfied with the performance of the unit. Service records indicate repeated problems with the ignition system. The original burner was replaced by AEHDP before finally removing the Destroilet. The unit was then installed in a new location. No long-term evaluation was possible, since the owners died before the current study was begun. No additional information concerning the use or performance of this Destroilet was available.

Unit A-6 was in service for only two years. One member of the family which used this unit indicated that it worked satisfactorily. The other stated that it often did not burn wastes completely. In any case, the unit was removed in 1972 because the ignition failed to operate reliably. The family used an outdoor privy after removing the Destroilet.

In summary, it is apparent that these three units were not reliable as a sole means for human waste disposal. Since the proper operation of the incineration process is essential for removing the wastes from the home, any failure becomes intolerable.

Total annual costs are high, especially considering that other household wastes are omitted from the process. This would discourage use by lower income families.

Beyond the questions of convenience and cost is the factor of safety. The degree of risk from explosions must be determined before any recommendations can be made concerning gas-fired incinerating toilets of this type.

Recycling Toilet Systems

In a home where potable water is in short supply, recycling of wastewater would be desirable. Even in 1968, many possibilities existed for recycling. Some recycling systems have recently been identified and evaluated by M. Milne, (4) R. Siegrist, (5) and others.

Direct recycling systems are available as commercial units. One which was available in 1970 was the Uniroyal recycling system. Two homes were selected for installation of these systems.

Description of the Unit--

The Uniroyal Recycling Toilet system consisted of an aerated digester, a recycling pump, a fractional horsepower air pump and a carbon filter. Figure 4 illustrates these components. The aerated digester was developed by

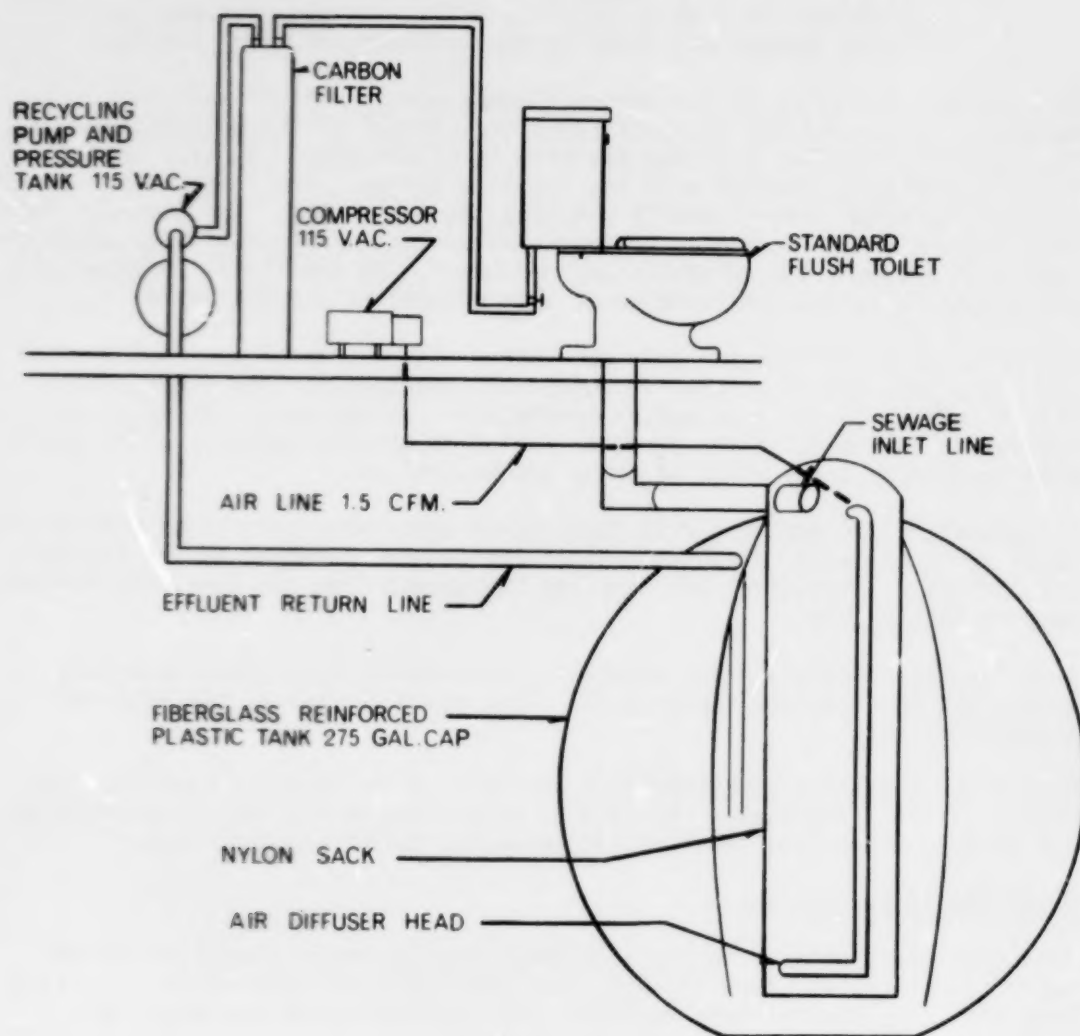


Figure 4. Schematic of recycle toilet system.

Carl Boester and Donald Bloodgood.

The digester consisted of a 1042 l (275 gal.) fiberglass-reinforced plastic (FRP) tank with a large nylon sack draped around an air diffusion head. This sack created a central zone for aeration of incoming wastes. The wastewater would then flow through the mesh of the sack into an outer storage zone for further oxidation before being recycled to the toilet. Solids were retained by the sack for digestion over an extended time period.

The recirculating pump was a standard 250 watt (1/3 hp.) water pump with an air pressure tank and controls. The air compressor was rated at 0.043 m³/min (1.5 CFM) and was wired to run continuously.

A metal tank packed with activated carbon was installed between the recirculation pump and the toilet. This filter was designed to remove objectionable color and odor. The tank was about 1.2 meters (4 ft.) in height and 230 mm (9 in.) in diameter. No backwashing system was provided.

The systems contained no provisions for overflow of wastes. More recent illustrations of this design show an optional overflow pipe and a high level shut-off switch on the recirculating pump. If the average adult produces about 1.33 liters (0.35 gal.) (7) of wastes per day, a total of 485 liters (128 gal.) per user would accumulate annually in the system. Since this annual accumulation equals 47 percent of the maximum tank volume, removal of excess material would be required several times per year.

Operation of the Recycling Toilet System--

Operation was as simple as flushing the toilet, for the user. No adjustment of any component was normally needed. However, frequent maintenance by a technician was required. A mechanically - inclined homeowner could probably perform all needed maintenance. Since the air compressor ran continuously, a lack of noise would serve as warning in case the compressor failed. The carbon filter also contained a self-monitoring feature in that any clogging would reduce the flow to the flush tank.

The operating sequence began with a 15 liter (4 gal.) toilet flush. The water from the toilet flowed by gravity to the central aeration chamber. Larger solids were retained in this central chamber, while the liquid portion and finely divided solids were filtered through the nylon bag into the outer chamber. The filtrate was retained in the outer chamber for an undefined period and recycled by the water pump. Where a carbon filter was used, effluent was pumped through the filter before returning to the flush tank.

The aeration tank was initially charged with about 0.757 m³ (200 gal.) of fresh water. Excess water and sludge were to be removed when the tank became full. As an alternative, an overflow to a subsurface absorption trench could be utilized to avoid the necessity of frequent removal and truck hauling of excess liquid. Still, removal of accumulated sludge would be required on a regular basis.

Installation Costs--

The purchase price of the aeration tank, aerator, carbon filter and water pump was about \$500 in 1970. Other materials cost about \$110. Installation labor for the treatment units totaled about 60 man-hours, including hand excavation of the hole for the aeration tank. At the locally prevailing rate of \$1.70 per hour for labor (1970), labor cost totaled \$102. Supervisory time by AEHDP was not recorded, but required supervisory time is estimated to be about 15 hours at \$4.20 per hour, or a total of \$63. These costs would indicate a total system installed cost of \$775 in 1970. Estimates for 1978 costs are listed in Table 14.

Operating Costs--

Electrical consumption and hauling of excess wastewater comprised the major operating costs. The compressor was rated at 125 watts per hour, which would consume 3.2×10^8 J (90 KWH) per month. The water pump operated intermittently as the toilet was flushed and pressure dropped in the pressure tank. With 7 flushes per day, about 0.14 m^3 (30 gal.) would be pumped per full-time user-day, or 4.2 m^3 (900 gal.) per user-month. At \$1.10 per million joules (4¢/KWH), water pumping would cost less than \$0.05 per month per user and aeration would cost \$3.60 per month. Total operating cost for a family of three would be about \$3.75 per month at these rates, and would have been about half as much in 1970-73.

Maintenance Costs -

Maintenance of the two recycling systems was curiously different, according to available records. One system (B-2) served three people and did not have a carbon filter. No maintenance calls were recorded for that system over a period of about 18 months.

The other system (B-1) served only one elderly lady and had a carbon filter. This system required 17 service calls involving 37 man-hours of time, not including travel. Although the filter seemed to have a chronic clogging problem, only 4.5 hours of time were recorded for filter servicing. The air compressor and associated line required 13.5 hours of service, including replacement of the compressor motor three times.

The diffuser head in the digestion tank became clogged and required servicing three times; this required 4 man-hours for special service calls plus part of another multi-purpose call. The digester tank was pumped out once during the two-year period. In addition to the actual pumping costs, an AEHDP staff member was on the site for 9 hours to clean the diffuser head, chlorinate the system, fill the tank and repair the air line. The recycling pump was apparently trouble-free.

The cost of all maintenance items was not recorded. A \$24 cost was recorded for one replacement of the air compressor. The carbon filter was replaced one time; the estimated cost for that is \$150. Pumping out the large tank was estimated to cost \$50. (In 1976 the tank was cleaned on the initiative of a septic-tank cleaning company; the charge for that service was an exorbitant \$120.) Maintenance man-hours could be estimated to cost \$350,

and travel for the 17 visits would total about \$41 at a rate of 20 miles per visit and 12 cents per mile. The total maintenance costs for the two year period would be about \$683 or \$341.50 per year for system B-1.

No ready explanation was found for the lack of similar maintenance costs for system B-2. The lack of a carbon filter would have reduced the costs by about \$195 or \$97.50 per year. But this would have had no effect on the remaining cost factors. There was a significant difference in the cultural level of the two families. System B-1 served a meticulous elderly woman in a small town. She used her telephone to call the AEHDP office whenever the system appeared to malfunction.

In contrast, System B-2 served a family which was at the lowest socioeconomic level. They lived near the end of a very steep unimproved road in a rather remote setting. They had no telephone. The only complaint this family made about the system was the cost of electricity to operate it.

These cultural differences may have affected the expectations of the users about the recycling systems. As long as the toilet flushed and the odor was not objectionable, system B-2 was viewed as working satisfactorily. But the person using system B-1 objected to discoloration of the flushing water and even low levels of odor. This very likely affected the frequency of maintenance calls made to the systems.

Life Cycle Costs--

It is difficult to draw conclusions about life cycle costs from the two systems described in this study. Seemingly, one system was subject to excessive service requirements while the other had no apparent need for maintenance. Estimates of waste accumulation show that a family of three would produce about 1,455 liters (384 gal.) of excess waste per year. This material would probably need to be removed several times per year, although this need is not substantiated by available records. For purposes of this cost estimate, it is assumed that three pump-outs per year would be needed at a cost of \$30 each, or \$90 per year.

Service calls are estimated to be required on a monthly basis. Twelve calls per year involving 1.5 man-hours per call at \$10 per hour would total \$180; travel costs for these calls would equal \$29 at 12 cents per mile and 20 miles per trip. Parts are estimated to average \$30 per year excluding the carbon filter. A local water service company reported a cost of \$30 to service a typical carbon-sand filter, not including labor or travel. Replacement of the carbon is anticipated to be required three times per year for a total of \$90 in materials. These maintenance cost projections are listed in Table 3.

TABLE 3 - 1978 ANNUAL MAINTENANCE COSTS PROJECTION: FOR RECYCLING TOILET

Labor: 12 calls x 1.5 hrs/call x \$10/hr	\$180
Travel: 12 trips x 20 miles x \$.12/mile	29
Parts:	30
Carbon Replacement: 3 replacements x \$30 ea.	90
Truck hauling of excess waste: \$30@ x 3 trips	90
Total Maintenance Cost	\$419

Average annual operating costs are primarily related to electrical consumption which equals about 38.7×10^6 J (1090 KWH). At \$1.10/ 10^6 J (4¢/KWH) annual operation would cost \$44. Therefore, the total operating and maintenance cost is estimated to equal \$463 per year or \$38.60 per month.

Added to this would be the annualized capital cost. The major mechanical components of the recycling system would appear to have useful periods of from 5 to 20 years.

Replacement costs and useful periods were estimated to be:

air compressor, \$100 in 5 years;
water pump, \$150 in 10 years;
carbon filter, \$350 in 10 years;
digestion tank, \$600 in 20 years.

At an interest rate of 10 percent, the total annual capital cost would equal \$178. When added to the annual operation and maintenance cost of \$463, a life cycle cost of \$641 per year is indicated.

Performance of Recycling Toilet Systems--

The two units had quite different performance characteristics, as was alluded to in the maintenance discussion. No analysis of recycled water was ever conducted by AEHDP. One unit had been "cannibalized" and the other had been converted to a septic tank by the end of the AEHDP's monitoring program.

Unit B-1 had been subject to odor and discoloration complaints. The carbon filter seemed to clog and become anaerobic after a few months. This was apparently the cause of some of the odor complaints. Odors also became objectionable because of compressor failure and air diffuser clogging.

After much effort to keep recycling unit B-1 operating, AEHDP offered to convert the aeration-digestion tank to a septic tank and to design a small absorption field for the small front yard. This work was completed in 1973.

Unit B-2 had no severe operating problems prior to removal of the compressor. The recycled water was high in fine suspended solids and was a medium brown color. The odor was reported to be not objectionable to the users. The users did complain repeatedly about the cost of operation, which finally resulted

in removal of the compressor by AEHDP. This compressor was then installed at unit B-1.

When interviewed in 1978, the users of unit B-2 said they liked the recycling toilet and would like to have it working again. They were using an outdoor privy at that time. They still had an inadequate supply of water, which was a spring on the mountain above the house. The seasonal inadequacy of the water supply was one reason the AEHDP had selected a recycling system for this location.

With both units, there was an obvious potential hazard to health from the recycled wastewater. Without disinfection, disease organisms could be present in the recycled water. Since no sampling for pathogens or indicator organisms was conducted, the degree of risk is unknown.

Extended Aeration With Sand Filtration

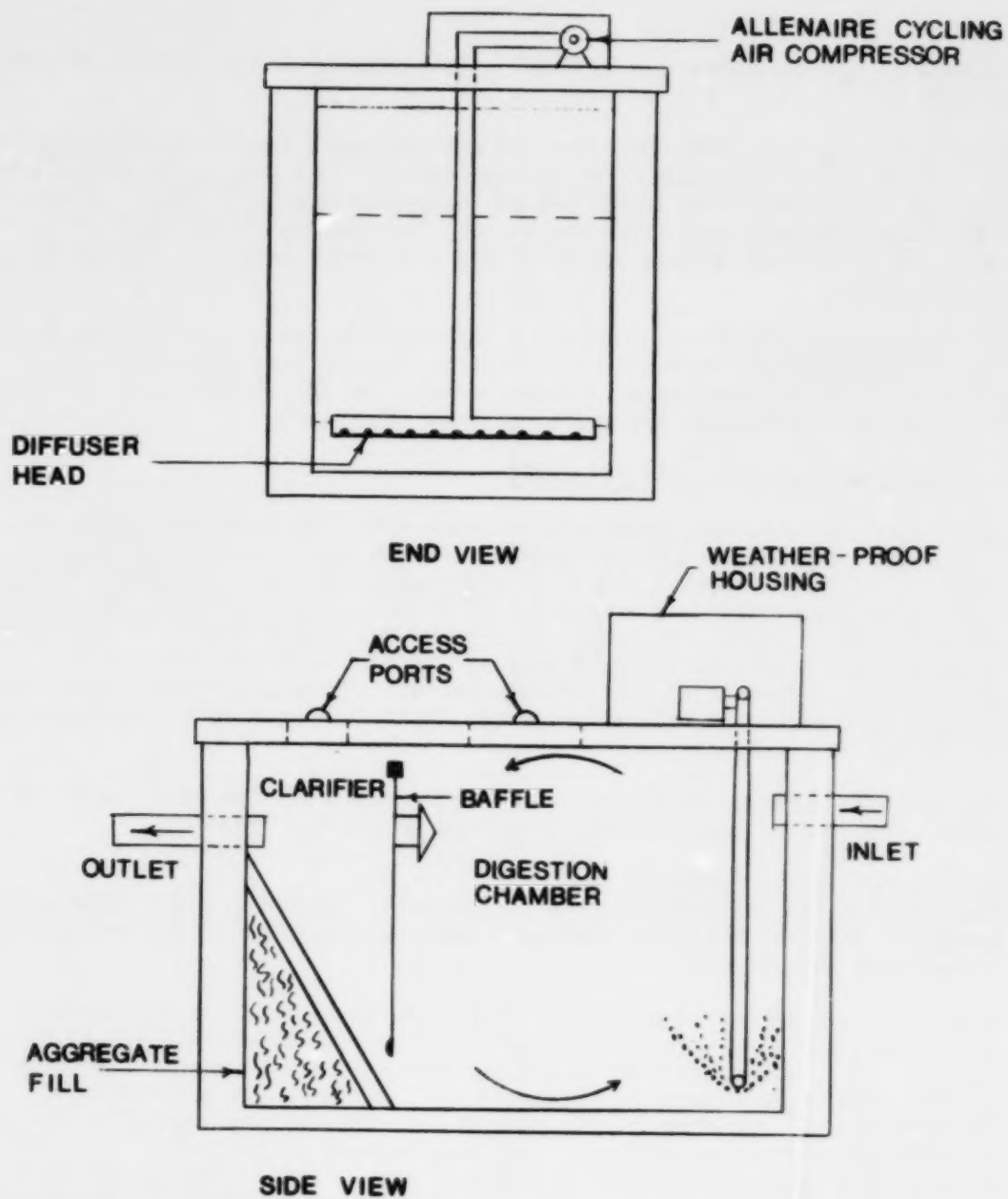
Small aerated tanks have been used for many years for treatment of sewage from homes. It has been proposed that aeration would produce effluent superior to that of septic tanks. Field studies of small extended aeration tanks have shown that this assumption is often not substantiated in actual installations (7,8). The AEHDP selected a very simple design of aerated tank in an attempt to obtain a system with low initial cost and reasonable reliability. Recognizing the inherent variability of aerated effluent, the Project used slow sand filtration to polish the effluent prior to discharge to the surface.

Two extended aeration with sand filtration (EA-SF) systems were installed by AEHDP. One served a single family and one served two families.

Description of the Systems--

The locations of the systems shown on Figure 1. System C-1 was designed to serve two families having a total of 9 persons. System C-2 was designed for a family of two persons.

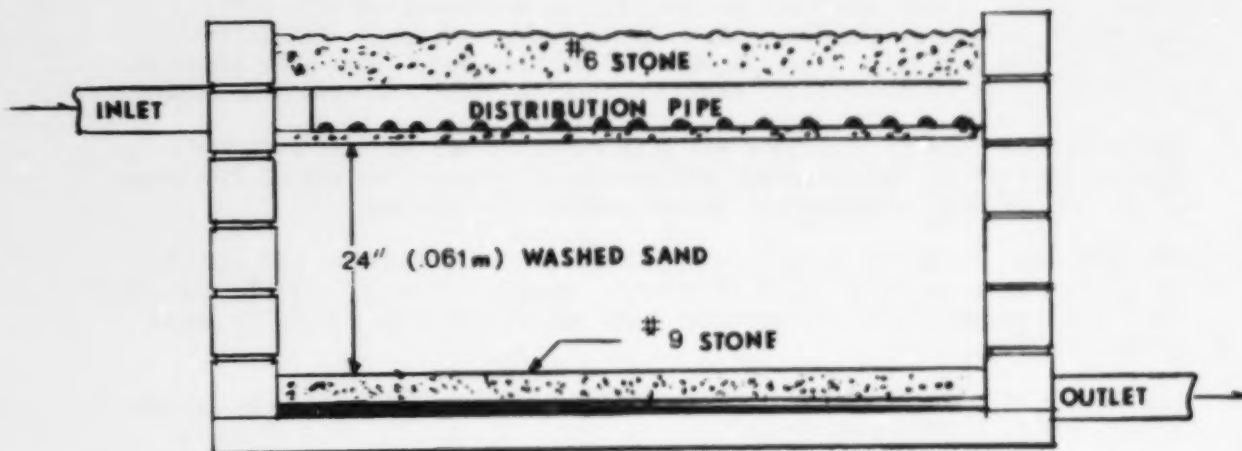
System C-1 was installed on a very steep site on the bank of the Middle Fork of the Kentucky River, in Leslie County. It consisted of a single aeration tank having a liquid capacity of 885 gallons and an open sand filter with a surface area of 80 square feet. Figure 5 illustrates the aeration tank. Figure 6 depicts the sand filter used in C-2, and C-1 was similar. The aeration compressor and diffuser were manufactured by Allenaire, Inc., of Warren, Ohio, and carried the "Septi-care" brand label. The compressor motor was rated at 248 watts (1/3 hp) and required 115 volts, 60 cycle AC current. Output was 453 m³/day at 2.1×10^4 Pa (16,000 cfm @ 3 psi). Available records indicate that both systems utilized the same model of compressor, with variable timer settings to provide the required volumes of air. The diffuser arm was of one-inch diameter plastic pipe with 48 holes of 2.3 mm (0.09 in.) diameter along the bottom side.



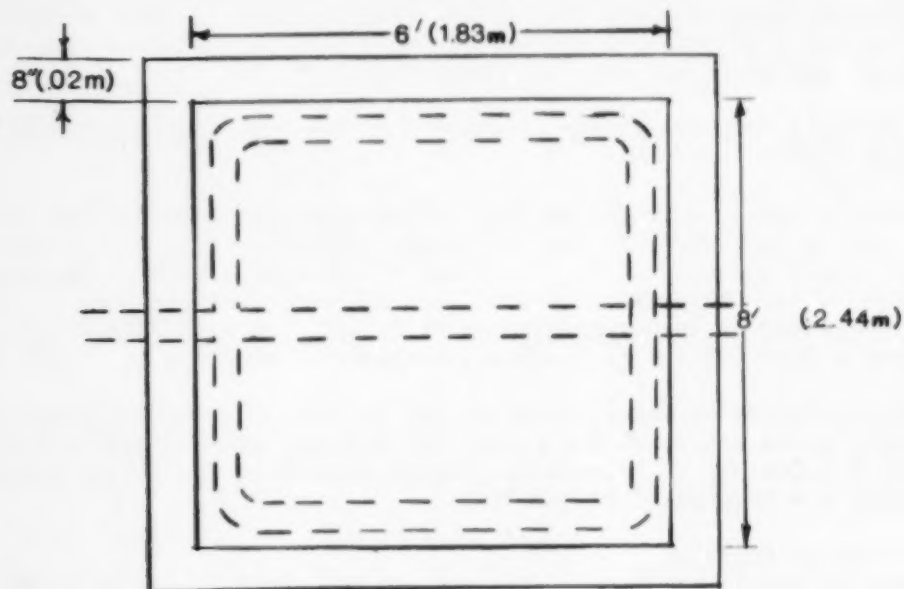
NOTE:

CAPACITY - 1060 GALLON
 COMPRESSOR $\frac{1}{3}$ H.P. 1600
 C.F.D. @ 3 P.S.I.

Figure 5. Extended aeration unit schematic diagram.



CROSS - SECTION



PLAN VIEW

Figure 6. Open sand filter diagram.

Sludge return in the tanks was by gravity; no mechanical or air lift mechanisms were provided for either sludge or scum return. The initial installations omitted a separate weir or overflow tee. Tees were added to the outlet pipe by AEHDP after realizing the need for improved scum retention.

The estimated flow to this unit was 0.68 cubic meters per day (180 gpd). Studies by Laak (6) would permit estimation of organic loading at 210 grams (0.45 lbs) of 5-day Biochemical Oxygen Demand (BOD) per day.

The open sand filter in system C-1 provided 7.4 square meters (80 sq. ft.) of surface in a concrete block structure. Because of shallow soils and other site restrictions, both the aeration tank and filter were partially above ground level.

The filter consisted of a 100 mm (4 in.) layer of No. 9 stone in the bottom, 610 mm (24 in.) of washed river sand and about 305 mm (12 in.) of No. 6 stone on top. Perforated bituminous fiberpipe 100 mm (4 in.) in diameter was used for both distribution of aerated effluent and as underdrain for discharge of filtrate. No soil cover was used over the uppermost crushed rock, which covered the distribution pipe. The soil cover was omitted for the purpose of increasing oxygen availability to the sand surface. At the estimated flow of 0.68 m³/day (180 gpd) the surface of the filter would have an average loading rate of 0.092 m³/m² per day (2.25 gpd/ft²).

The effluent from the filter discharged to the bank of the Kentucky River (Middle Fork).

System C-2 served only two persons and was somewhat smaller than C-1. It was located in a steep hollow in eastern Leslie County. The aeration tank had a liquid capacity of 2.0 cubic meters (520 gal.) with an identical air compressor and diffuser as system C-1. A clock-timer was used to operate the compressor in an adjustable on-off cycle. The sand filter had a surface area of 4.5 m² (48 sq. ft.) and was constructed as shown in Figure 6.

Based on studies of water closet wastes by Laak (6), the estimated loading to this system was about 0.2 m³/day (50 gal/day) total liquid and 47 grams (0.10 lbs) per day of 5-day BOD. Liquid loading to the filter surface would be about 0.1 m³/m² day⁻¹ (1 gpd/ft²).

Construction Costs--

Details of construction costs for systems C-1 and C-2 have been lost. It is known that the total construction cost for system C-1 was \$950 and for system C-2 was \$665, in 1970. The systems utilized ordinary construction materials such as concrete blocks, crushed dolomite, washed sand and perforated fiberpipe. Only the aeration compressors and diffusers were proprietary devices. Updated construction costs for a similar system of three person capacity have been estimated on the basis of local costs in the central Kentucky area, as shown in the following tabulation:

AERATION UNIT

Pre-cast Concrete Tank, 2.8m^3 (750 Gal.)	\$300
Aeration Equipment, Installed	250
Piping, Installed	<u>150</u>
Total Aeration Unit	\$700

OPEN SAND FILTER, 7m^2 (75 Sq. Ft.)

Crushed Rock, in place	\$ 50
Sand, in place	170
Concrete Block structure	200
Piping, in place	130
Excavation	<u>40</u>
Total Filter Cost	\$590

TOTAL SYSTEM COST, 1978 ESTIMATE \$1,290

Operating Costs--

The extended aeration air compressor created the main operating cost in this system. The aerator is rated at 248 watts (1/3 hp) and operates on an intermittent cycle. With the timer set for 40 minutes on and 20 minutes off, the compressor would consume $5.21 \times 10^9 \text{J}$ (1,447 KWH) per year. At a 1978 rate of 4 cents per KWH, the annual electric power cost would be \$58.

When compared to the incineration and recycling systems, water for flushing may also be considered an operating cost. Since both AEHDP installations utilized private water supplies, no water treatment costs were involved. Water pumping costs for flushing are estimated to equal less than 5 cents per user-month, or \$.60 per capita per year. With municipal water service at a rate of \$1.50 per thousand gallons (\$.40/ m^3), annual cost for flushing would be about \$14 per capita.

Assuming an individual water supply is used, total annual operating costs for a family of three would equal \$60.

Maintenance Costs--

During the initial 2 years of operation, no regular maintenance was required on the EA-SF systems. The manufacturer recommended twice yearly maintenance checks on the aeration equipment. These maintenance checks would include oiling the motor, checking air lines and diffuser and measuring sludge accumulation. Otis and Boyle determined that removal of sludge was necessary in

most extended aeration tanks on a schedule of 8 to 12 months. (8)

No maintenance or repairs were done on the two EA-SF systems until early 1978. Whether maintenance was actually needed before that time could not be positively determined. Preventive maintenance possibly could have avoided the breakdown of the air compressor in system C-2. This occurred in March, 1978, when a bearing locked and broke. The present owner did not realize that the unit required oiling. It is not known whether the previous owner had oiled the bearings.

In system C-2, no oiling had been done since the AEHDP terminated its activities in 1973. The compressor was still running in May, 1978. However, the air supply line to the diffuser had separated at a fitting and no air was entering the treatment tank. The bituminous fiber influent pipe had also broken, possibly from the heavy snows in January 1978. The owner of this system was blind and did not know about these breakdowns.

These observations would tend to support the recommendation for regular maintenance checks. Such checks should be done often enough to prevent excessive periods of malfunction. Weekly observations by the landowner would be advisable. More extensive inspections by a trained person should be done at least once each three months.

The annual maintenance costs would be about \$130 per year for aeration, as shown in the following tabulation.

ANNUAL MAINTENANCE COSTS FOR AERATION

Quarterly maintenance: 8 man-hours/year	
at \$10 per hour plus travel	
of 80 miles at \$.12/mi=	\$ 89.60
Sludge pumping and hauling=	<u>40.00</u>
Annual Maintenance Cost	\$129.60

Maintenance of the sand filters was limited to occasional weed removal on system C-2 during the 8 years of operation. No other maintenance was reported by the owners. Observations of the filters in 1978 revealed no formation of a distinct clogging mat and no ponding of effluent on the sand. A loamy soil-like accumulation was evident in the crushed rock between the sand and the distribution pipes.

An accumulation of solids in the distribution pipes of system C-2 had clogged some of the outlet holes. Test flushing of the toilet permitted observation of the rate of flow from the distribution pipe into the sand. A single toilet flush produced a slow trickle from two holes in the distribution pipe.

Approximately 25 minutes were required for all flow from the single flush to empty from the pipes and be absorbed by the sand. Many annelids and arthropods were observed living in the humus filled rock of filter C-2. It seemed likely that these organisms assisted in maintaining the permeability of the filter. It should be noted that this system was located in an area which was surrounded by forest, and many of the arthropods were species which are common in forest litter.

Although the sand did not appear to need immediate cleaning, the distribution pipes were in need of removal of accumulated solids. It appeared to be possible to flush the solids back into the tank with the aid of a garden hose. A tee fitting could be placed in the line to accomplish this task, and a siphon breaker should be used on the garden hose to avoid accidental back-siphonage. There had been some erosion of soil onto the uphill side of filter C-2. This may have contributed to blockage of outlet holes in the distribution pipe on that side of the filter.

Altogether, it appeared that maintenance of the filter would be limited to flushing of distribution pipes about every 5 years and, perhaps, replacement of crushed rock surrounding the distribution pipe after about 10 years.

Costs for these "maintenance" activities, if done by hired labor, are estimated to be \$20 for line flushing and \$80 for replacement of the top layer of crushed rock. This would indicate a filter maintenance cost of \$12 per year.

Adding the estimated operating costs of the system to these maintenance costs gives a total annual O & M of \$190 for aeration and \$12 for the filter or a combined total of \$202 per year. This is a projected cost for a family of three persons.

Life Cycle Costs--

The basic structure of the tank and filter should have a useful life of about 30 years when made of concrete. The aerator is estimated to have a life of 10 years with proper maintenance. The sand and lower gravel fill may also be assumed to have a life of 30 years. Using these periods and an interest rate of 10 percent, the annualized capital cost would be about \$136 for a system to serve 3 persons. Adding this cost to the annual operation and maintenance cost of \$202 results in an annual life cycle cost of \$338.

Performance of Extended Aeration - Sand Filtration Systems--

The performance of the EA-SF systems was not tested by AEHDP; only irregular observations were made during the initial two years of operation. The person assigned to the monitoring of the systems stated that he was unable to collect an effluent from either of the filters.

In 1978, three samples were collected and analyzed as part of this evaluation. These were taken from a hole drilled in the invert of the effluent pipe on system C-2. Since system C-1 was not operating during the 1978 evaluation period, no tests were made of that system.

The results of the analyses are shown in Table 4. These results are different in many respects from typical sand filter effluents. Most unusual are the levels of nitrate nitrogen, which ranged from 220 to 655 mg/l. These levels are considerably higher than any reported in literature available to the writer. Laak (6) reported a Total Kjeldahl Nitrogen (TKN) of 193 mg/l for water closet wastes.

It is possible that partial excavation of the rock and upper sand for purposes of inspection affected the performance of the filter. A moderately heavy rainfall occurred during the sampling period of May 5, and this may have increased the rate of newly available nitrate movement through the filter.

TABLE 4

LABORATORY ANALYSIS OF FINAL EFFLUENT FROM EXTENDED AERATION* & SAND FILTER SYSTEM C-2

PARAMETER	DATE		
	May 5	May 11	June 22
	CONCENTRATION		
5-Day BOD (mg/l)	21.0	5.0	20.0
Total Suspended Solids (mg/l)	24.0	1.0	21.0
Ammonia Nitrogen (mg/l as N)	27.8	16.7	4.9
Nitrate (mg/l as N)	655.0	220.0	220.0
Total Phosphorus (mg/l as P)	10.0	6.2	9.8
pH			8.0
Fecal Coliform (No./100ml)	0	0	700

*NOTE: Aerator was not operating

The lack of fecal coliform on the tests of May 5 and 11 is also unusual for such effluents. Even the count of 700 per 100 ml reported for June 22 is lower than expected from a filter receiving septic effluent. Since the aerator had not functioned since March of 1978, the filter influent had essentially been anaerobic for about two months prior to these tests.

An estimate of overall reduction in 5-day BOD can be made by using Laak's values for water closet wastewater (6). If the local water closet waste concentrations are similar to those studied by Laak, the estimated concentration of BOD would be about 310 mg/l. This would equal a total reduction of about 95 percent in the anaerobic tank and sand filter.

The original owners of this system are now deceased. The new owners, a family of four persons, expressed satisfaction with the performance of the system. Even with the aerator disabled, no objectionable odors had been noticed from the filter.

The owners of system C-1 had also been satisfied with their system. They did not object to the electrical service costs required to operate the aerator. They stated a desire to have the system repaired as soon as possible.

Septic Tank - Open Sand Filter Systems

Three homes were provided with septic tanks followed by conventional slow sand filters. The filters were constructed in the same manner as those used with the aeration tanks.

Description of the Systems--

One of the Septic Tank-Open Sand Filter (ST-OSF) systems could not be located in the field and no system description was found in the files. Therefore, no evaluation of that system was made. The other two ST-OSF systems utilized nearly identical components. A 1.1 m^3 (300-gal.) circular septic tank constructed of welded steel was used. The tanks were coated with factory-applied bituminastic material. After installation, all scratches were painted with a cold process bituminastic material.

The sand filters were constructed in the manner described for the aeration systems. Figure 6 on page 42 illustrates the type of construction used. Both filters had a surface area of 4.5 m^2 (48 sq. ft.). Effluent was applied to the filters by gravity flow through perforated bituminous fiber pipe 100 mm (4 in.) in diameter.

Both homes were located in areas of steep topography. System D-1 was located near Sassafras in Knott County. The home was occupied by two elderly persons and was perched on the base of a mountain about 15 meters (50 feet) from Sassafras Creek. The yard of this home becomes saturated with groundwater in the springtime, with many small springs and rivulets running off the mountain.

System D-5 served a single person and was located near Wootton in Leslie County. It was in a narrow hollow with many large boulders around the house. Soils are shallow and stony.

The water supply at system D-1 was a shallow well and hand pump. Since no funds were available for installing a pressurized water system, a hand pump was installed next to the water closet tank. The hand pump was used to fill the tank after each toilet flush.

Estimated flow for system D-1 was 0.19 m^3 (50 gal.) per day and for system D-5, $.09 \text{ m}^3/\text{day}$ (24 gpd).

Details of construction costs for these two systems have been lost from the files. The total cost of system D-1 was about \$520. It is assumed that system D-5 would have had an equivalent cost.

Updating these costs for a three person family results in a total system cost of about \$840, as shown in Table 5. This includes a minimum-sized 2.8 m³ (750 gal.) precast septic tank and a sand filter of 7 m² (75 sq. ft.). The cost estimate is shown in Table 5.

TABLE 5

1978 Construction Cost Estimate for ST-OSF System	
Septic Tank 2.8 m ³ (750 gal.)	\$250
Sand Filter 7 m ² (75 sq. ft.)	
Crushed Rock	50
Sand	170
Concrete Block Structure	200
Piping	130
Excavation	40
Total Filter Cost	\$590
Total System Cost*	\$840

*Plus flush toilet and sewer

These estimates are based on use of a local septic tank contractor and non-union labor. For an equitable comparison with the "sewerless" toilets, a cost of \$120 should be added for the flush toilet and house sewer. The total system cost would then equal \$960.

Operating Costs--

These systems have no true operating costs other than the cost of water for toilet flushing. In system D-1, the water was provided by a hand pump, and therefore there were no operating costs. System D-5 utilized a private water supply with electric pump. Costs for electricity to provide water for toilet flushing were estimated to total less than \$0.60 per capita per year, which was the annual operating cost for D-5.

Maintenance Costs--

No maintenance had ever been required for system D-5. The house was vacant during the field survey, but the owner's son lived in the adjacent house and provided information on the system.

System D-1 required repair of the flush toilet in 1978, requiring about ½ man-hour of time. The outlet pipe from the filter was about 0.3 m (1 ft.) above the Creek bed and the pipe had become covered with rocks and filled with silt and sand over the years. This material was removed in 1978, requiring about one man-hour of effort. Even though the pipe had been plugged for an indeterminate period, the filter was not completely flooded in April of 1978. The owner reported that he had replaced the hand pump leather in 1975.

These maintenance actions for system D-1 are estimated to have required 2.5 man-hours of time over the seven year period of use. Assuming a cost of \$10 per hour for labor and travel of 40 miles at 12 cents per mile, total maintenance labor would equal \$29.80. Parts are estimated to cost \$2.00 for the pump, so the total maintenance cost for the period would be \$31.80, or about \$4.54 per year.

Projected maintenance costs would include removal of septage and cleaning the filter and distribution pipes. Clogging of some outlet holes was observed upon excavating the filter. This clogging was similar to that observed in system C-2. It seemed that cleaning of the pipes would be necessary before many more months of use. However, no standing water was observed in the pipes during any of the field visits in 1978. With no pressurized water system in the home, these pipes would have to be cleaned manually by scraping. An alternative to cleaning would be replacement with new pipe at the same time that the upper rock was replaced.

Based on these observations, pumping of septage and replacement of the filter distribution system would be projected to be needed on a frequency of once in 7 years. These costs are estimated to be \$50 for pumping and \$80 for filter maintenance, or a total of \$130. This would equal \$18.60 per year.

Adding these projected maintenance costs to the actual maintenance costs would give a total annual maintenance cost of about \$23.00.

Life Cycle Costs--

Due to the susceptibility of metal tanks to corrosion, the life of such tanks is estimated to be not more than 10 years. At current estimated replacement costs of \$200 and an interest rate of 10 percent, the annualized capital cost for a 1.1 m³ (300 gal.) metal tank would equal \$32.

An alternative in remote mountainous areas would be a fiberglass reinforced plastic (FRP) tank. With an estimated life of 30 years and a current replacement cost of \$340, a 750 gallon FRP tank would have an annualized capital cost of \$36. A precast concrete tank would have a similar cost.

The main structure of the sand filter is estimated to have a life of 30 years. At a replacement cost of \$590 and interest at 10 percent, the annualized capital cost would equal \$62.60.

The total life cycle cost for a ST-OSF system to treat water closet wastes from a household of three persons is summarized below.

Annual operation and maintenance	\$ 24.80
Annualized capital for FRP tank	36.00
Annualized capital for sand filter	<u>62.60</u>
Total annual life cycle cost	\$123.40

Performance of Septic Tank-Open Sand Filter Systems--

Some aspects of performance have already been discussed in the sections on operation and maintenance. The owners of the two systems D-1 and D-5 were apparently satisfied with their systems. No complaints on either system had been recorded by AEHDP.

Some clogging of upper crushed rock and distribution pipe holes was observed in the filter on system D-1. This had not made a noticeable difference in the functioning of the system.

Effluent samples were collected from system D-1 on May 9 and 10 and on June 22, 1978. No records of sampling by AEHDP were found. The results of analysis of samples is listed in Table 6.

Most of these values are similar to other tests of sand filter effluents (9). The suspended solids were unusually high, particularly on May 10. The solids contents are believed to be partially a result of accumulated silt washing from the filter after cleaning of the outlet pipe. This explanation appears to correlate with the low nitrate nitrogen levels on May 9th and 10th.

TABLE 6
ANALYSIS OF SEPTIC TANK-SAND FILTER EFFLUENT FROM SYSTEM D-1

Parameter	Date of Sample		
	May 9	May 10	June 22
5-day BOD (Mg/l)	2	6	8
Total Suspended Solids (Mg/l)	28	590	28
Ammonia Nitrogen (Mg/l as N)	1.5	0.3	*
Nitrate (Mg/l as N)	7.5	2	140
Total Phosphorus (Mg/l as P)	0.4	1.6	2.7
pH	*	*	8
Fecal Coliform (No./100ml)	100,000	13,000	*

*Not Reported

Fecal coliform levels were higher than normal. This is attributed to the surcharged condition of the filter on May 9. The outlet pipe was clogged with silt, sand and rocks. This caused water to back up in the filter to a level which was about 200 mm (8in.) below the distribution pipe. In order to collect samples, the blockage was removed and the filter permitted to drain for about $\frac{1}{2}$ hour before sampling was begun.

Except for the need for disinfection of the final effluent, the performance of the systems using septic tanks with slow sand filters was adequate for the local environment.

Septic Tank - Horizontal Sand Filter Systems

Three homes were provided with systems which utilized septic tanks and subsurface horizontal sand filters (ST-HFS). The septic tanks were small welded steel units. The subsurface sand filters were a design that had been developed by Abney (10) in 1968. Two of these systems were still in use in early 1978; the home on the third system was vacant.

Description of the Systems--

The septic tanks were coated metal tanks identical to those described in section 5. Capacities were 1.1 m^3 (300 gal.) for all systems.

The sand filters were constructed in an open trench which was approximately 0.33 m (3.5 ft.) deep and 0.23 m (2.5 ft.) wide. No underdrain pipe was used in the filters; a bed of sand 300 mm (12 inches) deep in the bottom served as an underdrain and horizontal filter. Both horizontal and vertical sand surfaces were actually used as primary infiltration areas, but only the vertical surfaces were used as design areas. Figure 7 illustrates the method of filter construction used. A core of 10 mm (3/8 in.) crushed rock was placed between vertical layers of sand, all resting on the bottom 300 mm (12 in.) sand layer. The rock core and upper sand were topped off with a layer of 19 mm (3/4 in.) crushed rock (#6 stone) which surrounded the perforated distribution pipe. Local soil was used as backfill to prevent freezing of effluent. Mortar sand was used as the filter medium.

At the terminus of the filter, a graded crushed rock fill was used to retain the sand and to provide additional filtration. The anticipated sequence of operation in the filter was gravity flow through the distribution pipe outlets, the coarse rock, the medium rock and then the sand. After reaching the trench bottom, liquid would be absorbed by the soil until the percolative capacity of the soil was exceeded. The filtrate was then expected to move horizontally through the sand to the end of the trench, where seepage to the surface would occur.

A clogging mat as described by Winneberger (11) was expected to develop at the interface between the medium rock and the sand. This clogging would normally develop at the lower, horizontal surface and then, as ponding of liquid increased, would progress up the vertical rock-sand interface. Ideally, two equally sized filters would be alternated in use annually to permit resting, which would result in partial oxidation of the clogging mat.

This sequence of operation did not occur in the filters examined in this study. The AEHDP was never able to collect any effluent from any of the subsurface filters. The two filters still in use in May, 1978, did not have a visible effluent after 7 years of operation. The owners stated that no liquid was ever seen seeping from the ends of the filters. This finding will be discussed in the section on system performance.

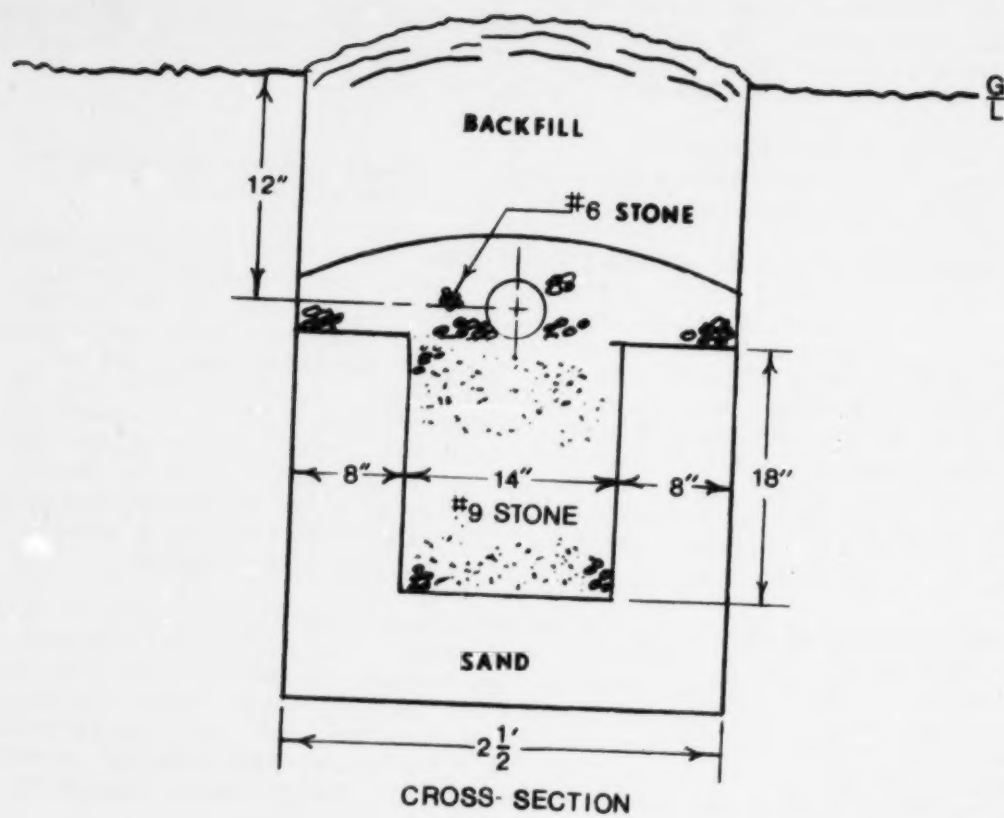


Figure 7. Cross-sectional view of horizontal buried sand filter.

At a design flow of 0.11 m^3 per day per capita (30/gpcd), the design loading rate on two filters was 15 liters per day/ m^2 (0.5 gpd/ ft^2), on the vertical rock-sand interface. The third filter was loaded at a theoretical rate of 52 l/d/ m^2 (1.25 gpd/ ft^2). The original design parameters of 0.11 m^3 /d/cap and 15 l/d/ m^2 would require a filter length of 6.1 m (20 ft.) per person, preferably in two equally sized filters which would be used alternately. The general specifications of each of the ST-HSF system are listed in Table 7.

TABLE 7

CHARACTERISTICS OF SEPTIC TANK-HORIZONTAL SAND FILTER SYSTEMS

System	Initial Number Of Persons	Sand Filter Design Flow l/da (gpd)	Volume of Septic Tank m^3 (gal.)	Design Area m^2 (ft^2)	Primary Filter Length m(ft)
D-2	2	230 (60)	1.1 (300)	11 (120)	12 (40)
D-3	5	570 (150)	1.1 (300)	11 (120)	12 (40)
D-4	2	230 (60)	1.1 (300)	11 (120)	12 (40)

System D-2 was located on a terrace of the North Fork of the Kentucky River. The house was located between a railroad track and the base of a mountain, and the front yard had been used as a roadway for a coal storage area in years past. The system was installed in the front yard and the bottom of the filter graded to drain into the railroad ditch. Figure 8 illustrates the general plan of the system.

System D-3 was located on a narrow bench above a road cut. The house had been constructed on the bench, which was made of broken sandstone and shale. Large stones made excavation of the trench difficult. Three adults and two children occupied the house at the time the treatment system was constructed in 1971. In 1978, only two adults still lived in the house. Figure 9 illustrates the general plan of this system.

System D-4 was located on a knob on the side of a mountain. The small side yard contained rocky soil which was excavated with pick and shovel for the treatment system. Figure 10 illustrates the general plan of this system.

Construction Costs--

The details of construction costs for these three ST-HSF systems were not available. It is known that the total cost was about \$600 each. Materials used in the filter included a minimum of 5.61 m^3 (7.33 cu. yd.) of washed sand, 2.7 m^3 (3.5 cu. yd.) of No. 9 stone, 1.9 m^3 (3.5 cu. yd.) of No. 6 stone and 15 m (50 ft.) of 100 mm (4 in.) perforated pipe. Total excavation required for the filter was about 12 to 15 m^3 (16 to 19 cu. yd.), not including excavation for the septic tank or house sewer.

Updated construction costs for a system to treat water closet wastes from three persons are shown in Table 8. These costs are based on installation by a local septic tank contractor using non-union labor. Total system costs

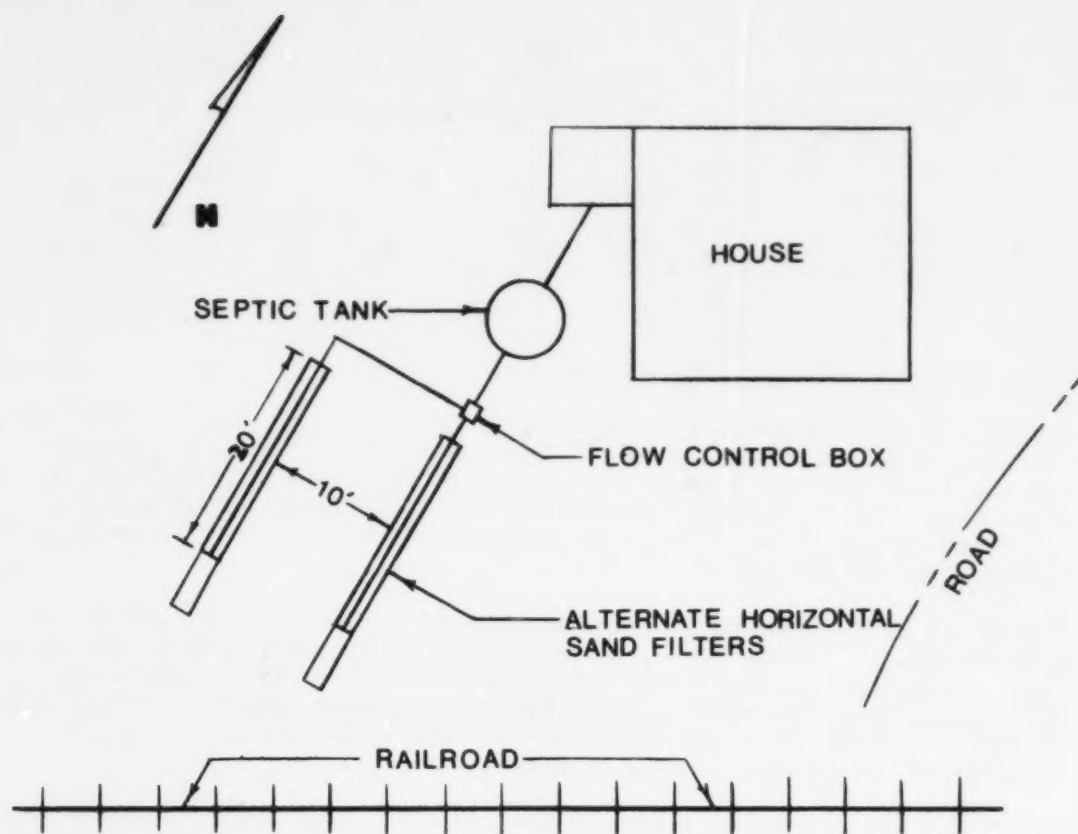


Figure 8. Plan view of system D-2.

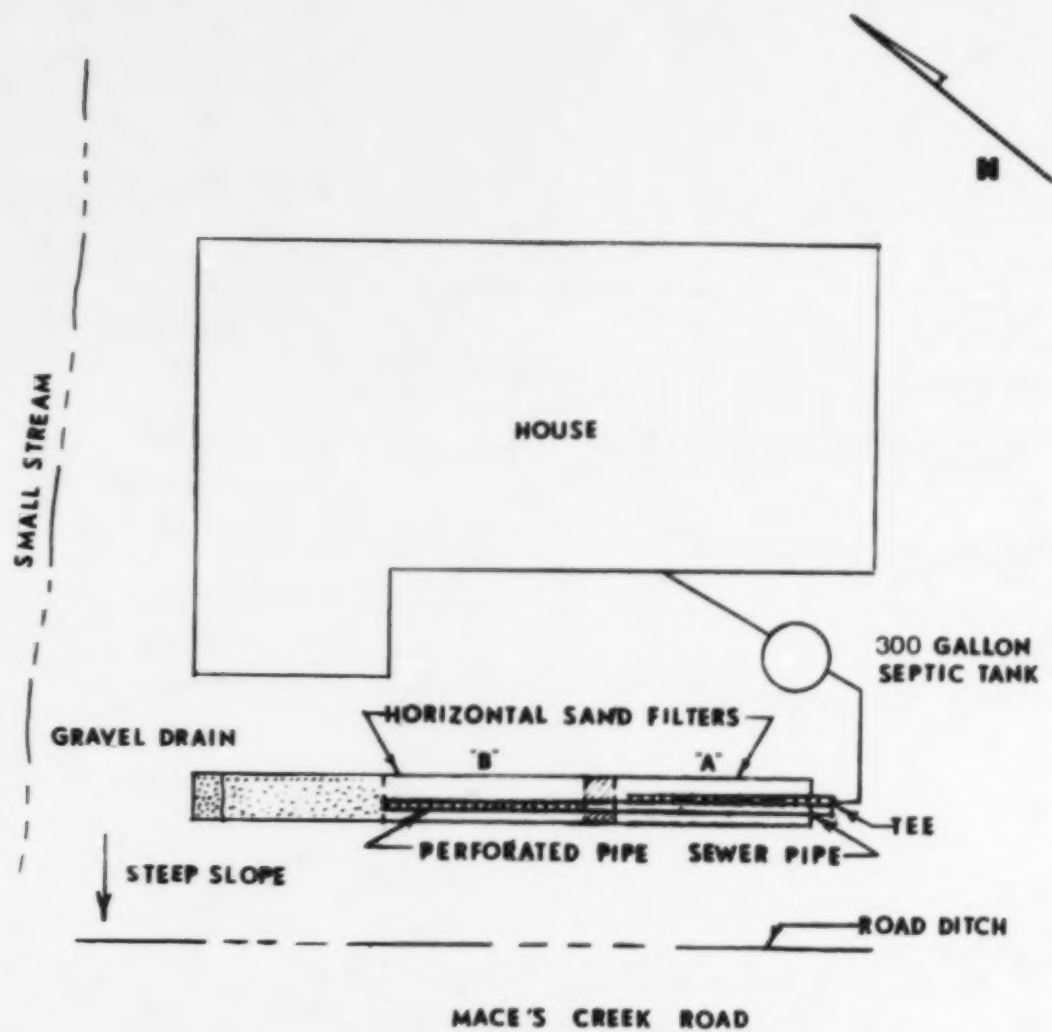


Figure 9. Plan view of system D-3.

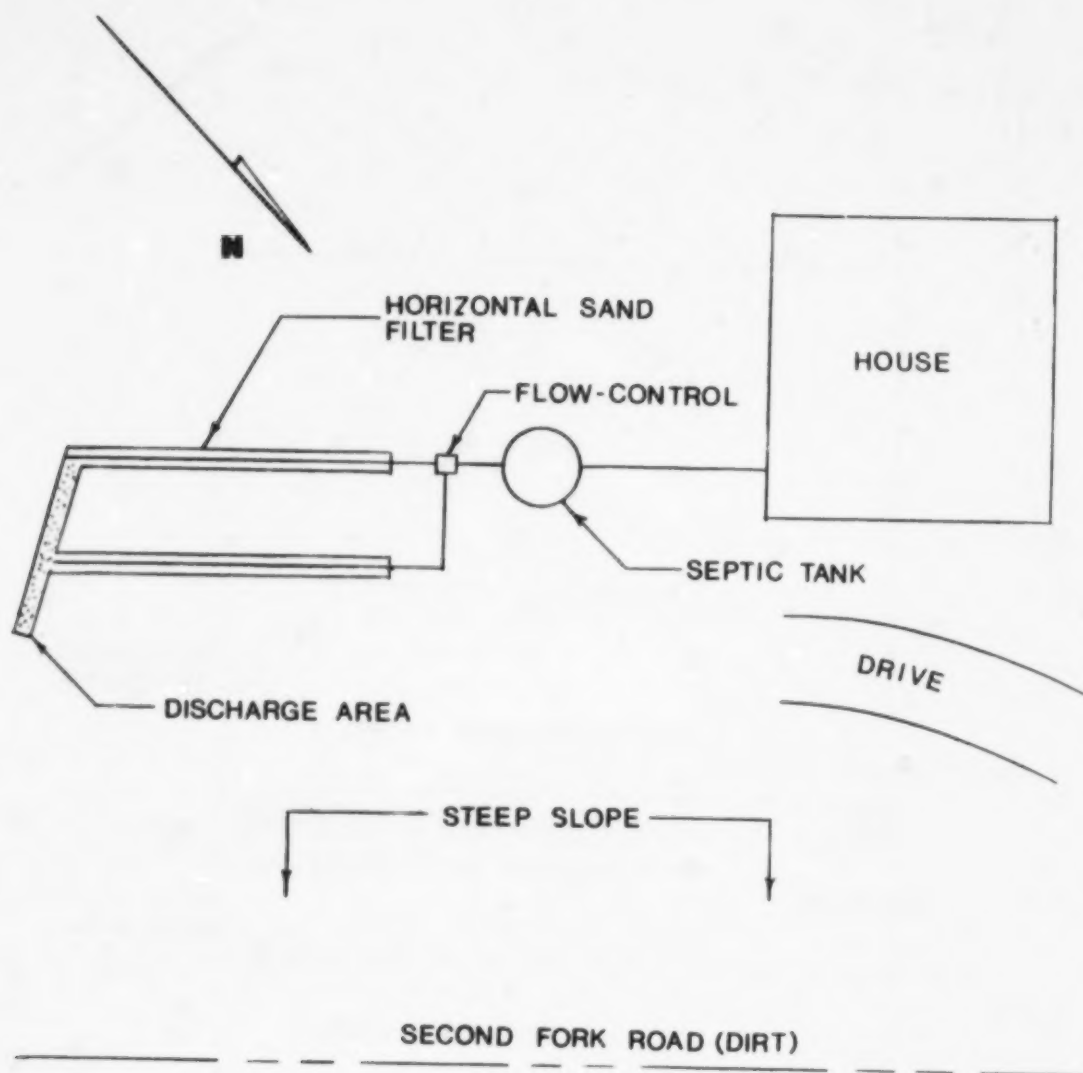


Figure 10. Plan view of system D-4.

would also include costs for installation of the flush toilet and house sewer, which may be estimated at \$120. So in a comparison with the incinerator or other sewerless toilets, the total cost would equal \$980.

TABLE 8
1978 CONSTRUCTION COSTS FOR SEPTIC TANK-HORIZONTAL SAND FILTER SYSTEM

Item	Cost
Septic Tank, 2.8 m ³ (750 gal.)	\$250
Horizontal Sand Filter (in-place costs)	
Sand 8.4 m ³ (11 CY)	260
No. 9 stone 3.5 m ³ (4.6 CY)	70
No. 6 stone 2.7 m ³ (3.5 CY)	50
Perforated Pipe 20 m ³ (70 L.F.)	100
Excavation 20 m ³ (26 CY)	130
Total Filter Cost	\$610
Total Treatment System Cost	\$860
Toilet and Sewer Cost	\$120
Total	\$980

Operating Costs--

The ST-HSF systems were simple gravity-operated systems with no significant operating costs. The cost for water to flush the toilet and carry wastes to the septic tank is the sole operating cost. This has been previously estimated to cost less than \$1.80 per year for electrical pump operation in an individual water supply system serving three persons.

Maintenance Costs--

Maintenance costs would include septic tank sludge removal and any repairs. None of these tanks had been pumped during the 7 year use period, and no repairs or other service had been required to any of the treatment components. If the sludge accumulation rate was equal to the 0.17 l (.04 gal.) per capita per day reported by Brandes (12), two of the tanks would have been full in 1974. Since investigation of sludge levels was not a part of this study, only the lack of noticeable malfunction can be used to evaluate septic tank operation. It would be normally recommended that tanks be cleaned every 3 to 5 years as preventive maintenance. It will be assumed that all of these systems will be cleaned in 1978, at a cost of \$50 each. This would equal an average annual maintenance cost of \$7.14 per year.

Life Cycle Costs--

Based on measurements of ponding in two of the filters, the anticipated life of the filters would be at least 30 years, and probably longer with good management of septic solids. If irreversible clogging should occur, the filter could possibly be treated with hydrogen peroxide as described by Harkin (13). Use of hydrogen peroxide for such treatment is patented and is legally available only from licensed operators. The current licenser, Port-O-Let of Jacksonville, Florida, reported a typical charge of \$325 for systems of a similar size. (Personal Communication)

Assuming a maximum useful life of 30 years for the filters as constructed, an interest rate of 10 percent and a 1978 construction cost of \$610, the annualized capital cost would equal \$65 per year. The metal septic tanks are expected to have a useful life of 10 years and a replacement cost of \$200. At an interest rate of 10%, these tanks would have an annualized capital cost of \$32. A more durable but more costly fiberglass tank would have an annualized capital cost of \$36 per year. Therefore, the 1978 annualized capital cost for the entire treatment system would equal about \$97 per year.

To this must be added the average annual operating and maintenance costs, which were projected to be about \$10. The 1978 annual life cycle costs would then be \$107 for a system serving three persons.

Performance of Septic Tank-Horizontal Sand Filter Systems--

As mentioned previously, these systems did not function in quite the mode of operation which had been anticipated. That is, no effluent was ever observed from any of these horizontal filters.

In order to evaluate the function of the filter and determine the depth of clogging in the sand, a special auger was made. It consisted of a cylinder of 4-inch thinwall conduit and a separate single-flight auger on a T-handle.

To use the auger, soil was excavated by post-hole digger to expose the crushed rock fill in the trench. The cylinder was then placed in the hole with the auger inside. The auger was turned to excavate the loose rock and sand. As material was withdrawn from the filter, it was examined for color and wetness and deposited in sequence for later replacement in the hole.

This procedure was used in evaluating system D-3. It was found that ponding had occurred in the first half of the system to a depth of 130 mm (5 in.) above the lower rock-sand interface. The lower part of the crushed rock and the upper two to three inches of sand were covered with dark slime and other anaerobic material. The lower 200 to 250 mm (8 to 10 in.) of sand was a normal brown color. (See Figure 11 for an illustration of these conditions.) The soil in the bottom of the trench was very moist but no water was standing in the lower sand. This was particularly significant in view of the fact that 21 mm (0.84 in.) of rain had fallen in the previous 48 hours at nearby Hyden, Kentucky.

The second trench in system D-3 had no evidence of ponded effluent. This condition would indicate that most of the effluent was being discharged to the first trench, which was 6.1 m (20 ft.) in length. According to a sketch from the AEHDP, this system was not provided with a flow-control box, as were systems D-2 and D-4. If all of the effluent was being discharged to the ponded area of the first trench, this would equal a theoretical loading rate of 152 l/m^2 per day (3.75 gpd/ft^2) in the earlier years and 61 l/m^2 per day (1.5 gpd/ft^2) in more recent years, on the area of submerged sand. These

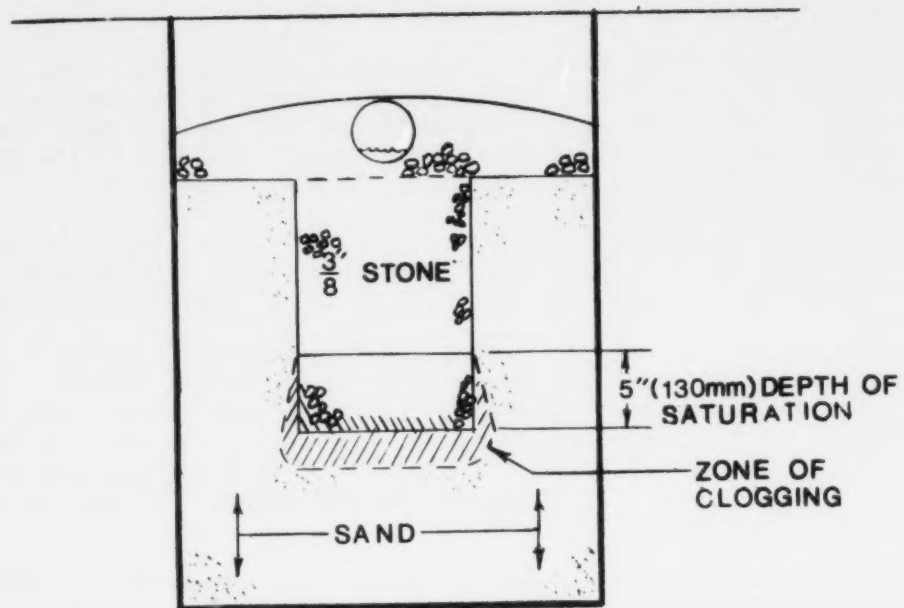


Figure 11. Clogging pattern in horizontal sand filter.

rates are probably in excess of the actual rates. This opinion is supported by the fact that one of the adults in this home prefers to use the outdoor privy, which is still maintained. He reportedly uses the flush toilet only in bad weather. In addition, studies by Laak (6) and others have shown that average flows from water closets are less than 76 l/cd (20 gpcd) in most homes, rather than the 114 l/d (30 gpcd) assumed by AEHDP personnel.

Using the more conservative flow data, estimated loading rates on the inundated area of filter D-3 would range from 91 l/m² per day (2.25 gpd/ft²) in 1972, to 31 l/m² per day (0.75 gpd/ft²) in 1978.

The terminal drain of system D-3 was excavated with shovels at two places. No saturation of the soil was evident, although moisture contents were fairly high. Small holes were excavated below the level of the filter bottom in an attempt to collect filtrate. No free water collected in the holes overnight. No septic odor was present in the end of the filter.

The condition of system D-2 was checked by partial excavation with shovels. Water levels in the parallel trenches were observed by driving perforated steel pipes into the system and measuring depths of accumulated liquid.

A flow control box is utilized in system D-2 as well as in system D-4. This box is a simple concrete box with two outlets, one to each trench. One of the outlets is blocked with an upturned plastic elbow fitting. The elbow can be moved from one outlet to the other in order to use the trenches alternately. This method of flow control was devised by Abney and incorporated in the septic tank regulations for Jackson County, Indiana, in 1967 (14). The box is illustrated in Figure 12.

Because the elbow was still in place and the owner stated that it had never been moved, it would be assumed that all of the flow for the past 7 years had been going to the same trench. This conclusion was supported by the observation of ponded water in the trenches. The trench in use had about 7 inches of water standing above the level of the lowest rock-sand interface, while the other trench had no evidence of saturation.

The loading rate on filter D-2 may be estimated from the assumed design flow and the observed depth of ponding. On the submerged portion of vertical sand surface (design area), the loading rate would equal 104 l/m²-day (2.6 gpd/ft²) in 1978. A more conventional estimate would include all rock-sand interfacial area; this would provide a loading rate of 52 l/m²-day (1.3 gpd/ft²) below the observed depth of ponding.

System D-4 was not in use during the current investigation. Visits by AEHDP between 1971 and 1973 revealed no evidence of effluent at the filter terminus. No complaints about this system were recorded by the AEHDP. The original owner used this system until her death in 1977. The property was not occupied in mid-1978.

It seems obvious that the horizontal sand filters had been functioning in the manner of absorption trenches. The percolative capacities of the stony soils

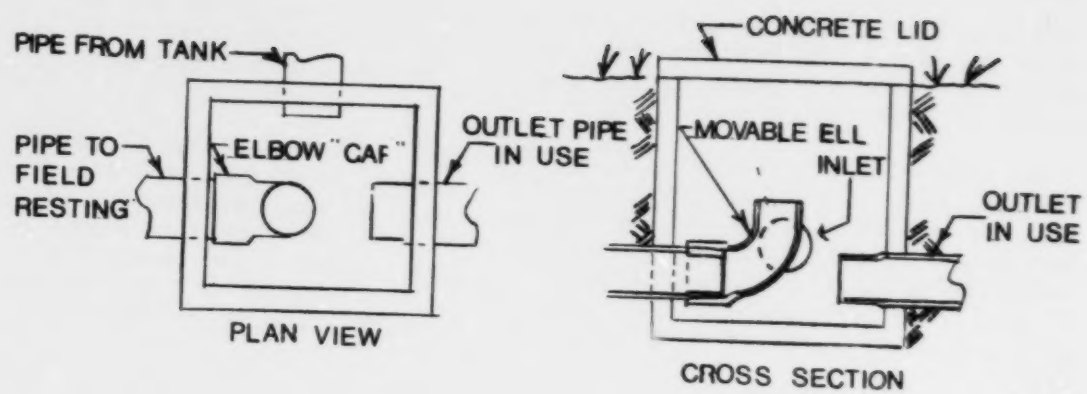


Figure 12. Flow control box used in ST-HSF systems.

in which the systems were installed were adequate for absorption of all effluents applied.

System D-3 appeared to be the most heavily loaded of the three systems. The active trench in that system has a bottom area of about 4.65 m^2 (50 sq. ft.). If the average flow in this system was $0.11 \text{ m}^3/\text{day}$ (30 gpd) in recent years, the trench bottom would have been loaded at a rate of 24 l/day m^2 (0.6 gpd/sq. ft.), or about 25 mm/day (1 in./day).

No permeability tests of the soil in system D-3 were conducted, but observation of soil next to the trench revealed that the soil between the broken stone had a sandy texture, with some silt and clay also present. Evidently the permeability of this material is moderately rapid.

Septic Tank-Soil Absorption Systems

Septic tanks followed by soil absorption trenches were installed at four homes initially. In addition, one recycling system was converted to a septic tank-soil absorption system (ST-SA). The location and current status of these systems was listed in Table 1.

These systems were installed at homes where the provisions of the plumbing code could not be met, but where the AEHDP staff believed that soil absorption systems could be designed to fit the site. The basic materials used were a metal septic tank, graded crushed rock and bituminous fiber pipe. A standard flush toilet was used with all of these systems. Two geometries of absorption trenches were installed. One was rectangular in cross-section, with a depth to width ratio of about 2:1. The other type was V-shaped in cross-section.

Description of System E-1--

System E-1 was located between U.S. Highway 421 and the small home, which was built about 15 feet from a rock cliff. The material in which the absorption trenches were installed consisted of about two to three feet of stony fill over original soil.

A 1.9 m^3 (500 gal) steel septic tank was installed. The effluent was piped to two absorption trenches without the use of a distribution box or flow control box. The general plan of system E-1 is shown in Figure 13.

The absorption trenches were hand excavated to a depth of 0.9 m (3 ft) and a width of 0.46 m (1.5 ft). Each trench was about 15 m (50 ft) long. The depth of rock fill below the distribution pipe was 1.8 feet 0.56 m . Total useful (bottom and sides) absorption area in this system equaled 47 m^2 (510 sq. ft.). Only the sidewalls were considered as design area, and provided 33.4 m^2 (360 ft.) of area. The cross section of a typical trench is shown in Figure 14.

Two sizes of crushed rock were used in these trenches as well as two other systems. This was done to comply with recommendations published by McGauhey

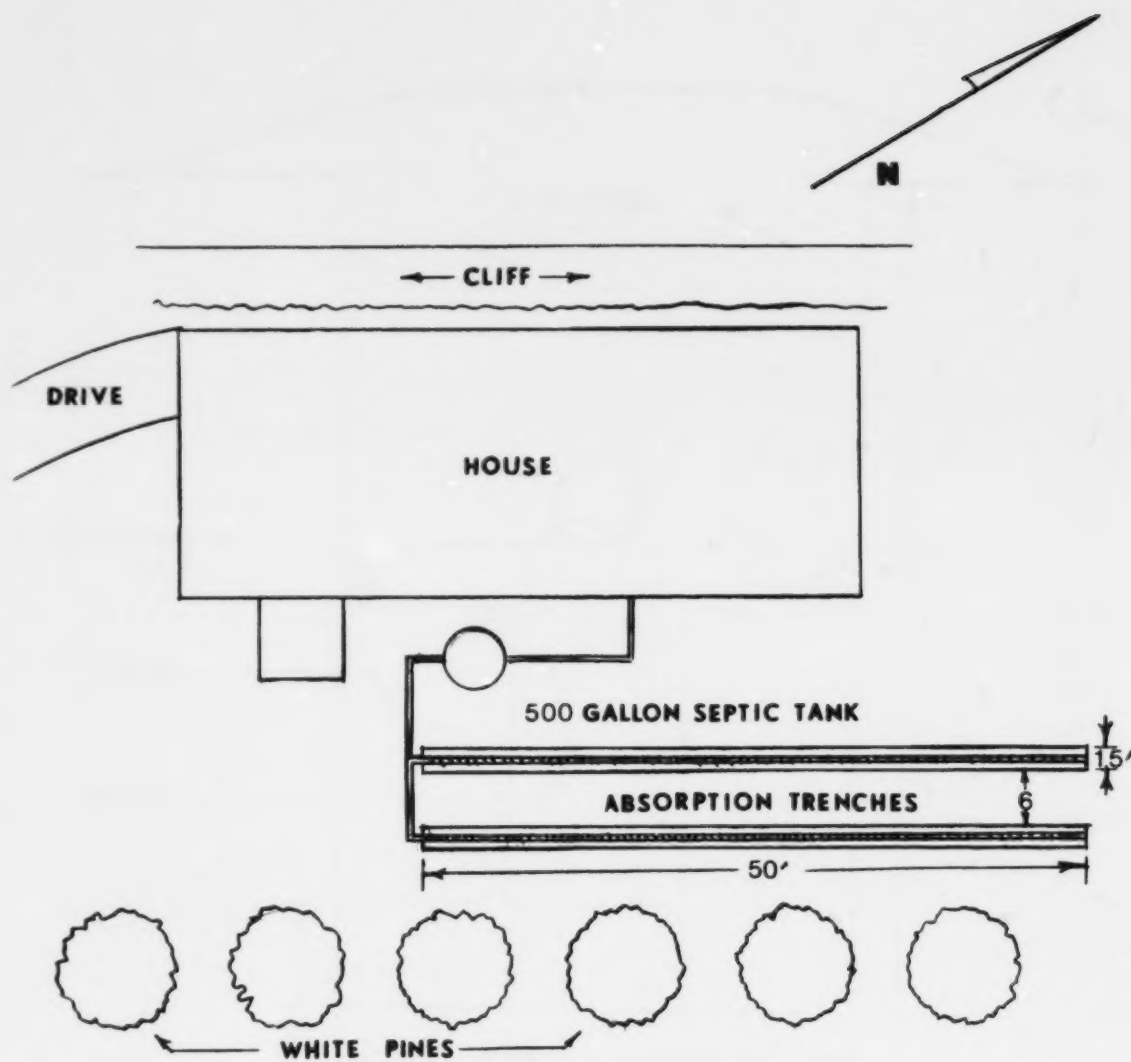


Figure 13. Plan view of system E-1.

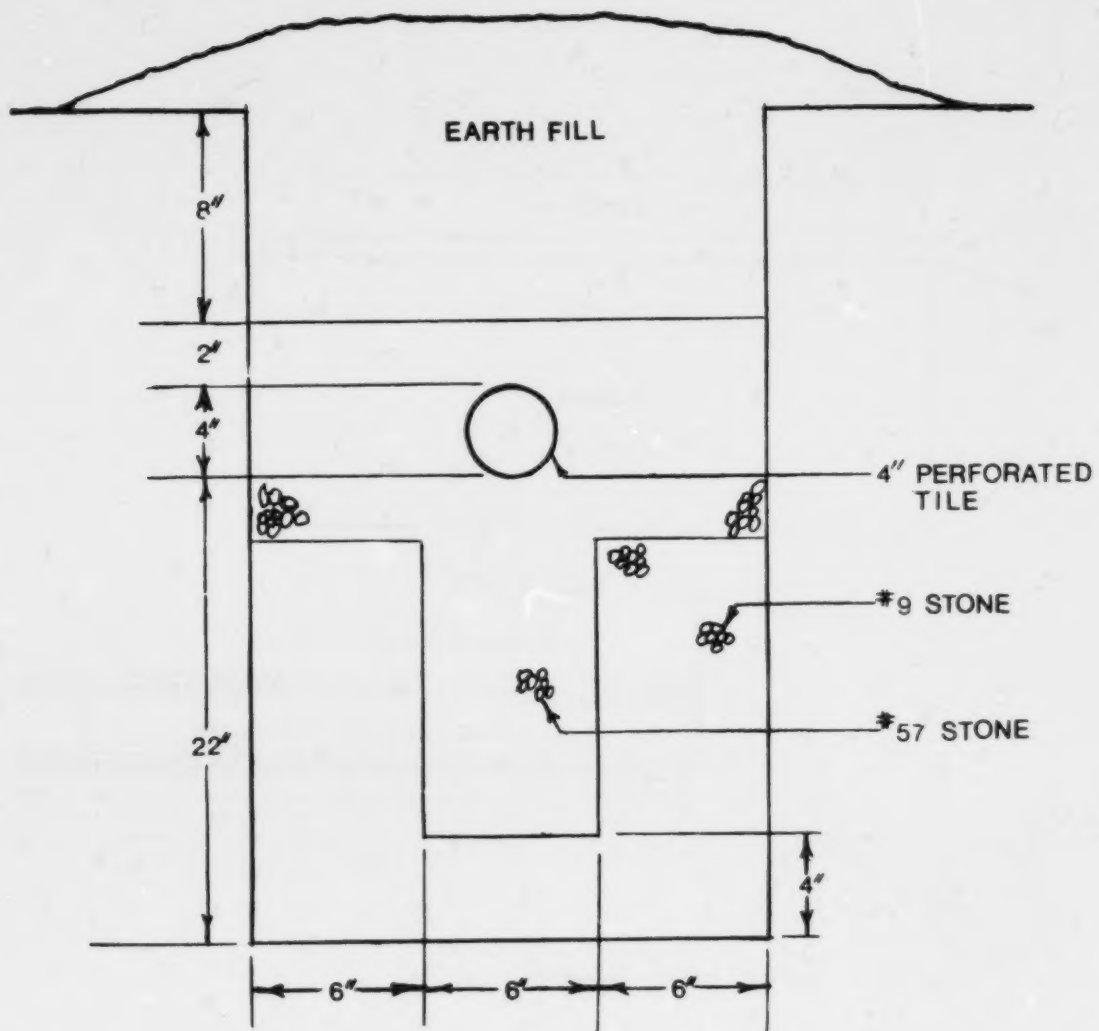


Figure 14. Cross-sectional view of sidewall absorption trench.

and Winneberger (11), for avoiding the "shadow zone" created by large stones in contact with soil infiltration surfaces. Later recommendations by Winneberger called for the use of washed sand rather than fine gravel for this purpose. (Personal Communication)

The water closet waste flow to system E-1 was estimated to average 150 l/da (40 gpd) from the two adults. This would equal a loading rate of 3 l/m²-da (.08 gpd/sq. ft.) or 3.3 mm/da (0.13 in/da), on the total available infiltration area. Considering trench bottom area alone, this flow would equal a loading rate of 11 l/m²/da (0.27 gpd/sq. ft.) or 11 mm/da (0.43 in./da)

Description of System E-2--

System E-2 incorporated a septic tank of 1.1 m³ (300 gal.) capacity and a single V-bottom absorption trench. It was installed in an abandoned road bed in the upper end of a steep hollow. The "soil" was stony fill and colluvial deposits. Three adults occupied the home in 1971. Figure 15 shows a typical section of the absorption trench, and Figure 16 shows the general plan.

The "V" shape of the trench was conceived as a means for reducing the volume of graded rock fill in comparison to that required for the standard Kentucky code trench. Excavation was done with pick and shovel. The two sizes of rock placed in the trench required the use of plywood forms to achieve the desired result.

The "V" absorption trench provides a total of about 1.5 sq. m (5 sq. ft.) of useful infiltration surface per foot. This is the sum total of the inclined sidewall and narrow bottom, all of which were about 1.2 m (4 ft.) lower in elevation than the outlet of the septic tank. The length of this trench is about 24 m (80 ft.), which would provide a total of 37 m² (400 sq. ft.) of infiltration area. These values should be considered rough estimates, since installation of this system did not involve precise measurements. At an estimated flow of 0.23 m³/da (60 gpd), the infiltration surface would have a loading rate of 6.1 l/m² (0.15 gpd/ft²) per day or 6 mm/day (0.24 in./da).

Description of System E-4--

System E-4 was similar to system E-2. (System E-3 will be discussed in the following section). A 1.1 m³ (300 gal.) septic-tank and a single V bottom trench was used. This system was installed about 30 m (100 ft) above Highway 28 on a steep slope in Perry County. Two elderly persons occupied the home until 1976. The home was vacant in 1978.

The absorption trench was approximately 18 m (60 ft.) in length, which was the maximum possible on that lot. This would provide about 28 m² (300 sq. ft.) of infiltration surface. The loading rate on the absorption trench was estimated to be 5.4 l/m²/da (0.13 gpd/sq. ft.) or 5.4 mm/da (0.21 in/da). The general plan of this system is shown in Figure 17.

Description of System E-3--

System E-3 was a special case and was not truly comparable to the other

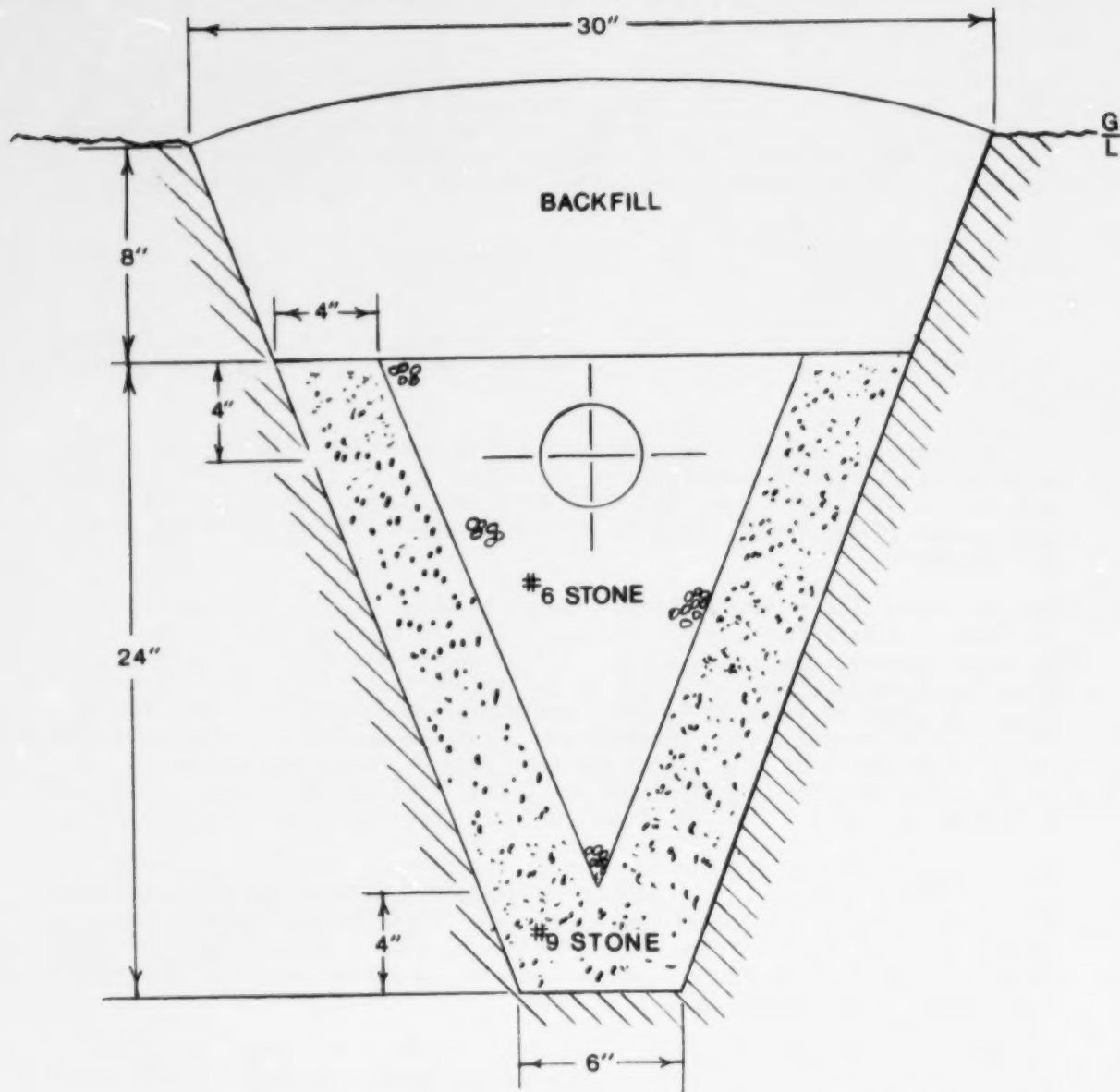


Figure 15. Cross-sectional view of V-trench.

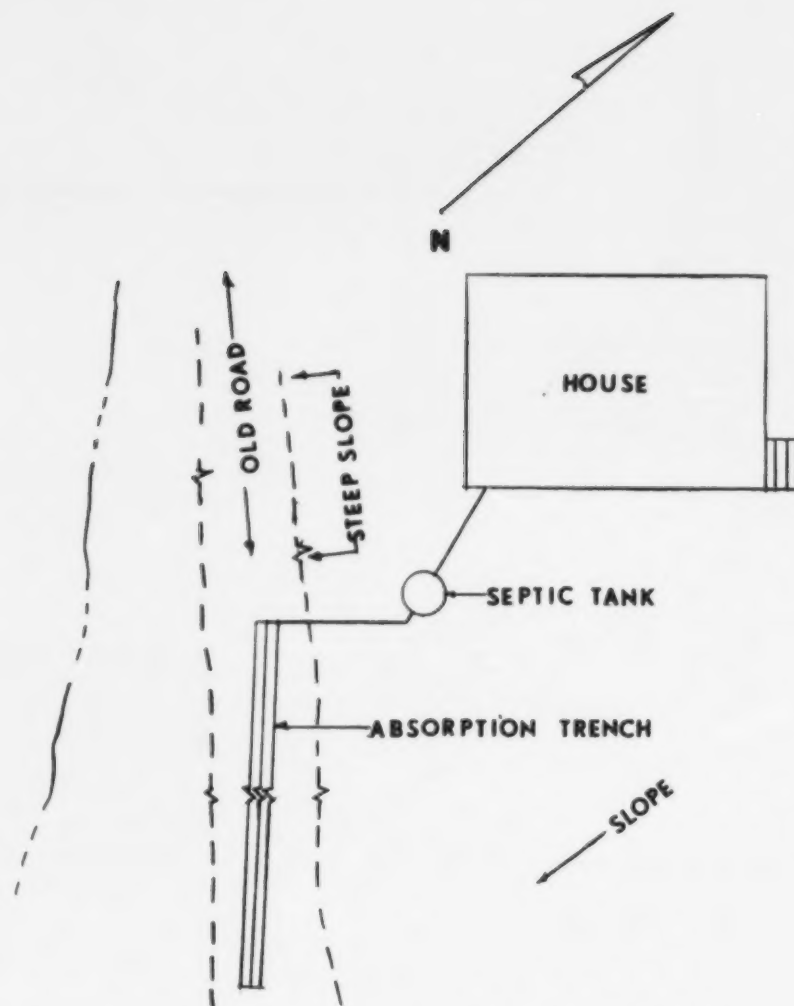


Figure 16. Plan view of system E-2.

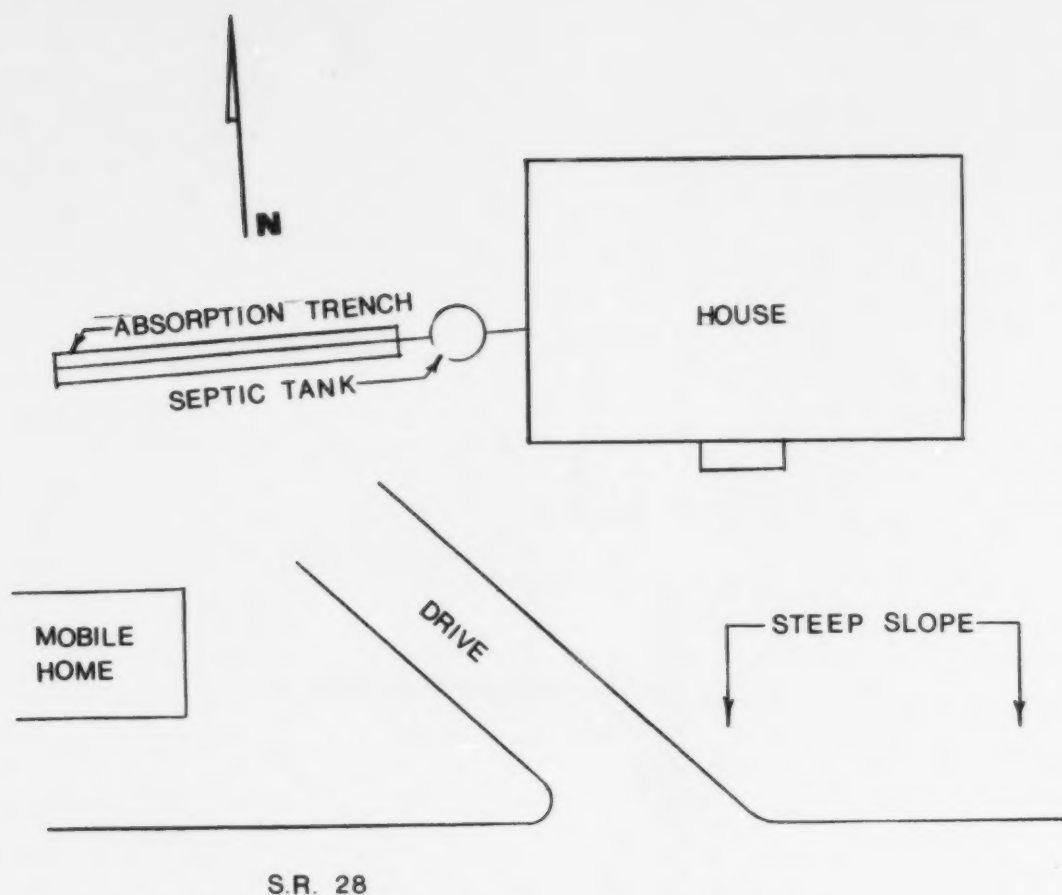


Figure 17. Plan view of system E-4.

systems. This system was designed by AEHDP, but private funds were used for construction. Unlike the other systems, the total wastewater flow (toilet, bath, kitchen, etc.) was treated.

This home was owned by the Frontier Nursing Service (FNS) a private home nursing organization. FNS requested the assistance of AEHDP in solving the wastewater disposal problem at this home. The home was located on a terrace above the North Fork of the Kentucky River, very close to a country road. A space about 30.4 m (100 ft.) in width was available between the road and the normal high water level of the river. The soil in this area was sandy loam alluvium.

A 1.9 m^3 (500 gal.) steel septic tank was installed, and a system of alternating absorption trenches was designed for the alluvial soil. The trenches were 0.3 m (1 ft.) in width and 0.9 m (3 ft.) in depth, with 0.6 m (2 ft.) of 13 mm (0.5 in) diameter washed stone placed below the distribution pipe. Total trench length was 73 m (240 ft.) which was divided among 5 short trenches. The design infiltration surface, the trench sidewalls below pipe level, totaled 89 m^2 (960 ft^2). Total useful infiltration area, consisting of bottom and sidewall, equaled 112 m^2 (1200 sq. ft.).

The estimated average flow in system E-3 was 760 l/day (200 gpd) from the four persons in the home. Therefore, the design loading rate on the sidewall infiltration surfaces was $8.42 \text{ l/m}^2/\text{day}$ (0.21 gpd/sq. ft.).

Description of Modified Recycling System (E-5)--

System B-1 was converted from an aerobic recycling system to a septic-tank soil absorption system. This was done because of chronic failure of the original system. The conversion was completed in early 1973. The available space in the front yard of this home was quite small, about 37 m^2 (400 sq. ft.). The yard was filled in behind a retaining wall which was about 1.1 m (3.5 ft.) high.

In order to convert the aeration tank to a septic tank, a fiberglass baffle was placed across the center of the tank and a plastic tee was placed on the outlet for improved scum and sludge retention. The nylon sock and diffuser were removed.

Small absorption trenches were dug by hand in the front yard. These trenches were about 200 mm (8 in.) wide and 0.76 m (2.5 ft.) deep. About 0.37 m (1.2 ft.) of crushed rock fill was placed below the 100 mm (4 in.) perforated distribution pipe. The total trench length was about 38 m (125 ft.), which provided about 35 m^2 (375 sq. ft.) of total available infiltration surface. The trenches were spaced about 1 m (3 ft.) center to center.

Only one elderly person lived in this small house. The estimated water closet flow was 95 l/day (25 gpd). Based on this estimate, the loading rate to the infiltration surfaces would be $2.7 \text{ l/m}^2/\text{day}$ (.07 gpd/sq. ft.) or 3 mm (.11 in.) per day. This system is shown in Figure 18.

A summary of the ST-SA system designs is presented in Table 9.

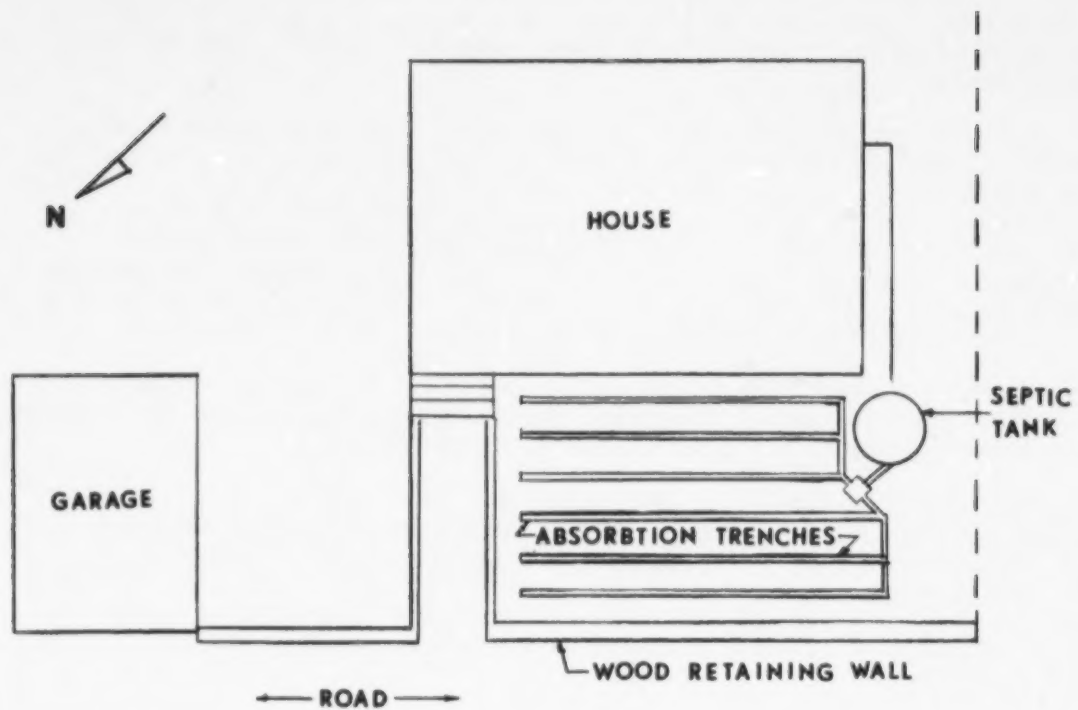


Figure 18. Plan view of modified recycling system.

TABLE 9 - CHARACTERISTICS OF SEPTIC TANK-SOIL ABSORPTION SYSTEMS

System	Initial Number Of Persons	Estimated Flow l/da (GPD)	Vol. of Septic Tank m ³ (Gal)	Total Infiltration Area m ² (Sq. Ft.)	Gross Loading Rates mm/da (in/da)
E-1*	2	150 (40)	1.9 (500)	47 (510)	3.3 (.13)
E-2 ‡	3	190 (60)	1.1 (300)	37 (400)	6.1 (.24)
E-3*	4	760 (200)†	1.9 (500)	112 (1200)	7.1 (.27)
E-4‡	2	150 (40)	1.1 (300)	28 (300)	5.4 (.21)
E-5(B-1)*	1	95 (25)	1.0 (275)	35 (375)	3 (.11)

*Sidewall absorption (Rectangular trench)

‡V-Bottom trench

†Total household flow

Construction Costs of ST-SA Systems--

Most of the records of construction costs of these five systems have been lost from the files.

An early report by the AEHDP stated that the construction cost for system E-1 was about \$700 in 1971. This was the largest of the publicly-funded ST-SA systems and probably represents the highest cost. System E-3 was privately funded, as was the conversion of system B-1.

Updated construction cost estimates for equivalent systems designed to treat water closet wastes from a 3-person household are presented in Table 10. Since no machines are available to excavate V-bottomed trenches, hand finishing of such trenches was assumed. These theoretical systems were designed for a volume of 230 l/da (60 gpd) and a loading rate of 10 l/m²/da (0.25 gpd/ft²) on infiltration surfaces. It is assumed that a graded fill consisting of washed sand and crushed rock would be placed as shown in Figures 14 and 15.

The total cost for a rectangular (sidewall absorption) trench designed on the stated criteria would be \$170, as compared to \$300 for a V-bottom trench. With a 1.9 m³ (750 gal.) septic tank, the total costs would equal \$420 for the rectangular trench system and \$550 for the V-bottom trench system. The difference in cost is due partly to the requirement for hand excavation and partly to the greater volume of sand and rock in the V-trench.

For comparison to the sewerless systems, a cost of \$120 must be added for the flush toilet and sewer. The total system costs in 1978 would then be \$540 for the rectangular trench system and \$670 for the V-bottom system.

TABLE 10
1978 CONSTRUCTION COST ESTIMATES FOR SEPTIC TANK - SOIL ABSORPTION SYSTEMS

SYSTEM TYPE	ITEM	COST
SIDEWALL ABSORPTION (RECTANGULAR) TRENCH	Septic Tank, 1.9 m ³ (750 gal.)	\$250
	Absorption Trench, 14 m (47 LF)	170
	Total Treatment System	\$420
	Toilet and Sewer	120
	Total	\$540
V-BOTTOM TRENCH	Septic Tank, 1.9 m ³ (750 gal.)	\$250
	Absorption Trench, 20 m (64 LF)	300
	Total Treatment System	\$550
	Toilet and Sewer	120
	Total	\$670

Operating and Maintenance Costs of ST-SA Systems--

Only costs for water to flush toilets have been identified as operating costs in ST-SA systems. As estimated previously, pumping 98 m³ (26,000 gal.) of flush water would cost less than \$2.00 per year for a family of three persons.

Maintenance costs would include removal of excess sludge and scum (septage), and performance of any needed repairs. Of these five systems, only one had had septage removed from the tank during the 5 to 7 years of use. It would be considered good practice to remove septage on a schedule of about each 3 to 5 years. It is assumed that these systems would require removal of septage in 1978 at a cost of \$50 each. This would equal an average annual maintenance cost of about \$7 per year.

Adding the estimated operating and maintenance costs gives a total annual O & M of \$9 per year.

Life Cycle Costs of ST-SA Systems--

As with the other septic tank systems, an annualized capital cost of \$36 is used for FRP tanks.

The absorption trenches appear to have an indeterminant useful life at current loading rates. Most of the estimated rates are less than one-half those recommended by Bouma (15) and Winneberger (11), which were based on formation

of an equilibrium clogging mat. The projected useful life of these absorption systems would therefore appear to be in excess of 30 years if piping materials do not fail in a shorter time. On the basis of a 30 year life, the annualized capital cost for the rectangular narrow trench would be \$18 and for the V-bottom trench would be \$32, at an interest rate of 10 percent. The total annual life cycle costs for the two systems are listed in Table 11

TABLE 11 - ANNUAL LIFE CYCLE COSTS FOR ST-SA SYSTEMS
FOR WATER CLOSET WASTES FROM 3 PERSONS

	Sidewall Absorption (Rectangular) Trench	V-Trench
Annual Operation and Maintenance	\$ 9	\$ 9
Annualized Capital-Septic Tank	36	36
Annualized Capital-Trench	18	32
Total	\$ 63	\$ 77

Performance of ST-SA Systems--

The performance of all five of the ST-SA systems has been satisfactory. No maintenance other than septage removal had been required. No evidence of any surfacing of leachate was noticed by either the AEHDP, the owners or by investigators in the spring of 1978.

Attempts were made to define the depth of ponding in the absorption trenches in 1978. This was done by locating the trenches with a steel probe and then driving perforated steel pipes into the crushed rock to the bottom of the trenches. Water levels were measured in the pipes and compared to the elevations of trench bottoms as determined by using the hand probe.

This procedure is not only limited in accuracy by physical soil-trench relationships, but also by the diurnal pattern of water use in a home. All water level readings made by use of the pipe and probe are estimated to be accurate within 50 mm (2 in.).

System E-1 was found to have liquid ponded to a depth of about 150 mm (6 in.) in one trench and about 25 mm (1 in.) in the other. System E-2 exhibited ponding of about 200 mm (8 in.); this was particularly difficult to measure, due to the shape of the trench bottom. System E-3 was not measured for ponding because of the presence of 0.9 to 1.2 m (3 to 4 ft.) of stony fill and crushed rock which had been placed over the absorption trenches; the area was being used as a truck refueling and parking lot. System E-4 was not measured for ponding because the home had been vacant for two years. System E-5 was found to have ponding to maximum depths of about 130 mm (5 in.). These findings are summarized in Table 12.

TABLE 12 - PERFORMANCE OF ABSORPTION TRENCHES

System	Soil/ Media*	Percolation Rate	Loading Rate		Maximum Depth of Ponding	Ponded Area as % of Total
		Min/cm (min/in)	mm/da(in/da)	mm (in.)		
E-1	Stony Loam	3.5 (9)	3.3 (0.12)	150 (6)	40-50	
E-2	Stony Loam	NA	6.1 (0.24)	200 (8)	40	
E-3	Sandy Loam	NA	7.1 (0.27)	NA	NA	
E-4	N/A	NA	5.4 (0.21)	NA	NA	
E-5	Colluvial Loam	NA	3.0 (0.00)	135 (5)	50	

*See Appendix for Soil Descriptions.

The Area Soil Scientist of the U.S. Soil Conservation Service performed evaluations of soil morphology on the disposal sites in 1978. His report is contained in the Appendix. He reported that he has modified some of his previous recommendations on use of some soils as a result of the obvious success of the demonstration systems.

SECTION 5

SYSTEM COMPARISONS

The seven types of treatment-disposal systems are compared for site requirements, costs and performance in the following section. These evaluations and comparisons are based on the characteristics of the systems as installed in the AEHDP area and do not necessarily reflect the characteristics of more recent modifications of similar systems.

SITE REQUIREMENTS

Site requirements for systems include the general requirements for the successful installation and operation of the particular system. The requirements related to soils, interior space, exterior space, power supplies, water supply and minimum weather protection are listed in Table 13.

The incinerating systems have the least complex site requirements, since most waste is discharged to the atmosphere. Residual material is dry and can be disposed as solid waste. Experience in AEHDP would indicate that densities of incinerating toilets would be limited by the potential for creation of highly objectionable odors. The main site requirements for electrically heated units are interior space equal to a flush toilet and electrical power. For gas-fired units, a source of natural or bottled LP gas is also required. A suitable means for exterior discharge of combustion products is required for both electrical and gas-fired units. Electrical components require protection from precipitation.

The flush water recycling system required slightly more interior space for the pump and filter, plus about 2 m² (20 ft²) of exterior space for the aeration tank. It may be feasible to install such tanks within the house structure, such as a basement or cellar. This has been proposed in extreme northern climates. Electrical power of 500 watts, 115v, 60 Hz was required. This system required no water supply except for an initial filling of about 800 liters (200 gal.). Protection from freezing was required, and electrical components required protection from precipitation. Control of noise from the aerator was needed.

The aeration tanks with open sand filter for treatment and discharge of flush water required interior space for a flush toilet plus about 9 m² (100 sq. ft.) for the aeration tank and filter. Electrical power of 250 watts, 115v, 60 HZ was required. Water supply equal to 80 to 110 l/day (20 to 30 gpd) per person was required for flushing the standard water closet. Pressurized water for filling the flush tank was optional but normally would be provided. This system would appear suitable for use with water conserving designs of flush toilets. The piping in this system required protection from freezing, and the aerator required protection from precipitation. No problem from freezing

TABLE 13
SITE REQUIREMENTS FOR HUMAN BODY WASTE TREATMENT SYSTEMS
FOR 3 PERSONS

SYSTEM	SOIL	AREA m ² (ft ²)	POWER TYPE	WATER SUPPLY	WEATHER PROTECTION
		Interior/Exterior			
Incinerating, Electrical	None	1.1(12) 0	60 Hz Electric	0	Precipi- tation
Incinerating, Gas	None	1.1(12) 0	110V, 60 Hz Electric & Gas	0	Precipi- tation
Recycling, Water	None	1.4(15) 1.9(20)	110V, 60 Hz Electric	800 l(200 gal) (Initial Charge)	Freezing, Precipi- tation
Aeration with Sand Filtration (Flush Toilet)	None	1.1 (12) 9(100)	110V, 60 Hz Electric	230 l/da (60 gpd)	Freezing Precipi- tation
Septic Tank, Open Sand Filter (Flush Toilet)	None	1.1(12) 9(100)	optional	230 l/da (60 gpd)	Freezing
Septic Tank, Horizontal Sand Filter (Flush Toilet)	1 m(3ft.)	1.1(12) 11(120)	optional	230 l/da (60 gpd)	Freezing
Septic Tank, Narrow Trench Soil Absorption (Flush Toilet) and/or V-bottom Trench	1.2 m(4ft.) (Varies with site and soil type)	1.1(12) 37(400)	optional	230 l/da (60 gpd)	Freezing

in the open filters was reported. A suitable point of discharge for treated effluent was required.

The septic tanks with open sand filters had requirements similar to the EA-OSF systems except that no electrical power was required for the treatment system. Where a pressurized water system was used, then part of that electrical power requirement would be used for filling the flush toilet. Interior space for a flush toilet, exterior space of about 9 m² (100 ft²) and water supply of about 80 l/day (20 gpd) per person were required.

Septic tank-horizontal sand filter systems had basically the same site requirements as the ST-OSF systems with the addition of a soil requirement. Since this filter was about 1 m (3 ft) in depth and soil was the supporting material, this depth would be required. It would seem to be possible to construct such a filter with treated wood, concrete block, native stone or other material as the supporting sidewall structure. Soil materials could also be imported, compacted and then excavated. But such alternatives would increase the construction costs above those shown.

The septic tank-soil absorption systems had more stringent soil requirements than the other systems. The minimum requirement was about 37 m² (400 ft²) of suitable soil with 0.9 to 1.2 m (3 to 4 ft) of depth, depending on the design of the absorption system. The soil should have adequate permeability for transport of the effluent and that portion of local precipitation which infiltrates the soil. The soil should contain clay and/or silt fractions to provide removal of pathogenic organisms; coarse sand and gravel deposits may not provide adequate treatment in all cases. The colluvial deposits in Eastern Kentucky seem to be suitable for use as effluent absorption media. The ST-SA systems also require space for a flush toilet, protection from freezing, and about 80 l/day (20 gpd) of flush water per person. These systems appear suitable for use with water-conserving designs of flush toilets.

COMPARISON OF COSTS

All costs in the comparison have been adjusted to 1978 data. Construction costs were estimated based on local costs in eastern Kentucky. It was assumed that all work would be performed by small local (non-union) contractors. Where possible, 1978 prices for manufactured units were obtained; this was not possible with the Uniroyal recycling system and the Allenaire air compressor. Costs for the various system types to serve a family of 3 persons are listed in Table 14. Annual life-cycle costs were computed at an interest rate of 10 percent.

The system with least capital and annual costs was the septic-tank with soil absorption of effluent in a narrow trench. This was due to both the low capital cost and very low operating-maintenance cost. At \$63 per year annual life cycle cost, the ST-SA system cost only one-tenth as much as the recycling system. This does not imply that recycling would necessarily always be 10 times as costly as a ST-SA system. The greatest cost for the recycling system was the annual maintenance cost; this should be reducible by improved system designs to about that shown for the EA-OSF systems, or \$140 per year.

TABLE 14
COMPARISON OF PROJECTED COSTS FOR ALTERNATIVE
TREATMENT SYSTEMS FOR HUMAN BODY WASTES IN S.E. KENTUCKY

DESIGN USE: 3 PERSONS						
SYSTEM	1978 CAPITAL COST \$	ANNUAL OPERATING COST \$	ANNUAL MAINTENANCE COST \$	AVERAGE MONTHLY O & M \$	ANNUAL LIFE-CYCLE COST \$	
Incinerating, Electrical	850	300	67	31	541	
Incinerating, Gas	750	182	91	23	426	
Recycling, water (w/flush toilet)	1300	44	419	39	641	
Aeration & Open Sand Filtration (w/flush toilet)	1290	60	142	17	338	
Septic Tank & Open Sand Filtration (w/flush toilet)	960	2	22	2	123	
Septic Tank & Horizontal Sand Filtration (w/flush toilet)	980	2	7	0.75	107	
Septic Tank & Narrow Trench Soil Absorption (w/flush toilet)	540	2	7	0.75	63	

The second most economical system was a septic tank with horizontal sand filter (ST-HSF), and the septic tank-open sand filter (ST-OSF) was a close third. At \$107 per year, the ST-HSF was 70 percent (\$44) more costly than the ST-SA system. The ST-OSF was only slightly higher at \$123 per year. If the homeowner did his own filter cleaning, then the annual costs for the two septic tank - filtration systems would be virtually equal.

The annual costs for the incinerating systems appear to be higher than most lower-income families would be willing to pay, at the current prices of electricity and gas. At monthly operation and maintenance costs of \$31 for electrical incineration and \$23 for gas incineration, lower income families could hardly afford these systems even with a 100 percent grant to cover capital costs.

The aeration tank-open sand filter system had a moderately high annual cost. The factors of high capital cost and high maintenance cost were primarily responsible for this ranking.

COMPARISON OF SYSTEMS PERFORMANCE

The performance of the various systems has been ranked in Table 15 for the factors of user acceptance, health protection, safety, energy conservation, overall environmental impact, longevity and frequency of maintenance. The numerical rating system used ranges from "unacceptable" (1) to "excellent" (5). These ratings cannot be added to derive an overall composite for each system because the various factors are not equal in significance.

These rankings are based on the systems as installed in the AEHDP area. The effect of recent design improvements has not been considered in this ranking. For instance, septic tanks made of fiberglass or concrete materials would have raised the "longevity" rating for the systems which utilized septic tanks.

TABLE 15
PERFORMANCE COMPARISON OF
ALTERNATIVE TREATMENT SYSTEMS
FOR HUMAN WASTES
AS INSTALLED IN SOUTHEASTERN KENTUCKY

SYSTEM	USER ACCEPTANCE	HEALTH PROTECTION (not safety)	SAFETY	ENERGY CONSERVA- TION	LONGEV- ITY	FREQUENCY OF MAINTEN- ANCE
Incinerating, Electrical	2	3	3	1	2	2
Incinerating, Gas	2	3	1	1	2	2
Recycling, Water (flush toilet)	2	2*	4	2	3	1
Aeration & Open Sand Filter (flush toilet)	4	2*	4	2	3	3
Septic Tank & Open Sand Filter (flush toilet)	4	2*	4	5	4	4
Septic Tank & Horizontal Sand Filter (flush toilet)	5	4	4	5	4	4
Septic Tank & Soil Absorption	5	5	4	5	4	4

1 = unacceptable; 2 = poor; 3 = good or acceptable; 4 = very good; 5 = excellent

* without disinfection

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APPENDIX A

SERVICE AND REPAIRS TO SYSTEMS THROUGH NOVEMBER, 1972

Unit	Number Persons	Visits For Repair	Time - Hrs.	Parts Cost	Type Repair
A-1	1				
A-2	3	3	3.5	1.00	Replaced corroded wire, replaced fuse
A-3	2	7	15.5	Est. \$40 (donated)	Adjusted spark plug gap, adjusted air fuel ratio. Replaced timer, motor, & cleaned fan & air switch.
A-4	2	15	24.0	Est. \$30. (donated)	Set air ratio, repair ignition, replace motor, clean fan & air switch.
A-5	3	9	11.0	Est. \$20	Reset air ratio, repair ignition, adjust regulator, replace burner, repaired leak in gas line.
A-6	4	3	6.5	0.00	Clean fan switch, clean fan, adjust air fuel ratio.
B-1	1	17	37.0	24.00	Cleaned diffuser head, replace motor compressor, repair carbon filter & replace, repair air lines, pumped tank.
B-2		1	1.5	0.00	Removed pump compressor, timer & controls.
C-1	8	3	4.0	20.22	Replace commode bowl, cleaned out valves in commode tank.
C-2	2	8	22.0	49.57	Sealed tank, installed baffle, pumped tank.

(Continued)

TABLE A-1 (Continued).

Unit	Number Persons	Visits For Repair	Time - Hrs.	Parts Cost	Type Repair
D-1	2	0			
D-2	2	0			
D-3	5	0			
D-4	2	0			
D-5	1	0			
D-6	3	0			
E-1	2	0			
E-2	3	0			
E-3	4	0			
E-4	2	0			

SERVICE RECORDS

ELECTRIC INCINERATING TOILETS

	<u>TIME</u>
A-1 C. Huff - rewired for ground, wire & connectors	3.5
rewired corroded leads to coil, design weakness	4.0
complaint report	1.0
delivered letter	0.5
removed Incinolet	3.0
A-2 W. Watts - visited on complaint	0.5
wire loose	2.0
fuse had been removed	1.0

GAS-FIRED INCINERATING TOILETS

A-3 H. Smith - removed & cleaned nozzle, adjusted spark plug	2.5
air fuel ratio	1.5
complaint about short cycle, lengthened it	2.0
reset air fuel ratio, cleaned burner fan	3.0
removed timer	1.5
installed new timer, adjusted spark	2.5
removed & replaced motor, adjusted spark plug	2.5
A-4 A. Ward - reset air fuel ratio, cleaned fan switch	2.0
replaced spark plug wire	1.0
complete disassemble motor bearings	3.5
aligned fan in housing	1.5
aligned fan in housing	1.5
cleaned burner	0.5
adjusted fan in housing	2.5
removed motor, bearings worn out	2.0

GAS-FIRED (con't)	<u>TIME</u>
A-4 A. Ward - installed new motor	2.0
cleaned burner, adjusted air	1.5
cleaned burner	1.0
removed motor & fan to clean fan	1.5
installed motor & fan	1.5
spark plug wire faulty, cleaned burner	1.0
replaced spark plug wire	1.0
A-5a K. Callahan - reset air fuel ratio	1.5
checked gas, switched tanks	1.0
could not get to fire	1.5
checked all systems, unit would barely function	1.0
could not get to fire, seemed to be out of fuel, checked spark plug	0.5
unit working perfectly after regulator was adjusted	0.5
new burner	1.5
removed unit	2.5
A-5b G. Wilson- fixed gas leak	1.0
A-6 J.M. Blair - adjusted air fuel ratio	1.5
dismantled unit, cleaned burner, fan & switch	3.0
cleaned fan switch	2.0
B-1 J. Gibson - new air compressor installed	2.0
trouble shooting problem with filter	1.5
replaced carbon filter, increased pump pressure	2.5
odors and solids in commode, cleaned.	0.5
dug up tank to check on air lines	3.5

GAS-FIRED (con't)	<u>TIME</u>
B-1 J. Gibson - removed compressor	1.5
redug hole for tank (access)	1.0
installed compressor, no air into tank, line plugged	1.5
pumped tank, cleaned diffuser head	4.5
chlorinated tank, filled with water, repaired air lines	4.5
pumped chlorine solution, primed pump, refilled tank	4.5
repaired air line in ground	1.5
repaired air line under house	0.5
installed compressor, unclogged diffuser head	1.5
unclogged diffuser head	2.5
took out compressor; motor burnt out	1.5
replaced motor, rewired switch	2.0
B-2 D. Combs - removed compressor, controls & pump	1.5
AERATION SYSTEMS	
C-1 W. Caldwell - broken commode bowl, removed	0.5
replaced commode bowl	2.5
cleaned out valves in commode	1.0
C-2 S. Kilburn - water seeping out of ground complaint	1.0
put "TEE" baffle on outlet	3.5
to plan ditch for effluent	1.0
tank leaking complaint	0.5
pumped tank to repair it	4.5
dug around walls	4.0
painted part dry, dipped excess water	3.5
finished paint and ditched surface	4.0

APPENDIX B
SOIL DESCRIPTION

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

P.O. Box 897, Hazard, Kentucky 41701

August 16, 1978

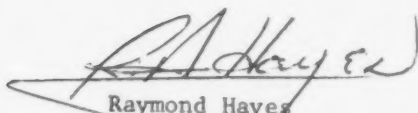
Parrut, Ely & Hurt
Consulting Engineers, Inc.
620 Euclid Avenue
Lexington, Kentucky 40502

RE: Soil Evaluation for Appalachian Sewage Disposal Project

Soil evaluation studies were made on 6 of the 7 sites in Perry, Letcher and Leslie counties. The access road to Mrs. Chester Lawson's home was blocked by strip mining equipment.

All of the disposal systems were installed in disturbed soil material. For all sites except Blackey and Ulvah the soil material is similar to the Shelocta Series. The sites at Blackey and Ulvah differ in having mixed colluvial and alluvial material; however, they have similar physical properties as far as sewage systems are concerned.

From a past hole size pit, I could not detect any evidence of failure, nor did I see any reasons to suspect they might fail.


Raymond Hayes
Soil Scientist

Attachments

SHELOCTA SERIES

The Shelocta series is a member of the fine-loamy, mixed, mesic family of Typic Hapludults. These soils have dark grayish brown silt loam Ap horizons and yellowish brown silty clay loam distinct Bt horizons; coarse fragments, 3 to 15 inches in size, are common throughout the soil.

Typifying Pedon: Shelocta silt loam - cultivated
(Colors are for moist soil.)

- | | | | |
|------|----|--------|---|
| Ap | -- | 0-10" | --Dark grayish brown (10YR 4/2) silt loam; weak fine granular structure; friable; 5 percent coarse fragments; many roots; medium acid; clear smooth boundary. (7 to 11 inches thick) |
| B2lt | -- | 10-20" | --Yellowish brown (10YR 5/6) heavy silt loam; weak medium subangular blocky structure; friable; 10 percent coarse fragments; thin clay films on faces of peds and in pores; common roots; very strongly acid; gradual wavy boundary. (10 to 20 inches thick) |
| B22t | -- | 20-32" | --Yellowish brown (10YR 5/6) silty clay loam; moderate medium subangular blocky structure; firm; 15 percent coarse fragments; thin continuous clay films on peds; very strongly acid; clear wavy boundary. (10 to 20 inches thick) |
| B23t | -- | 32-46" | --Yellowish brown (10YR 5/6) silty clay loam; weak medium subangular blocky structure; firm, slightly sticky, slightly plastic; 45 percent coarse fragments; thin clay films on peds and lining pores; very strongly acid; gradual wavy boundary. (12 to 20 inches thick) |
| C | -- | 46-54" | --Yellowish brown (10YR 5/4) silt loam; coarse fragments coated by silts comprise 40 to 60 percent of the volume; very strongly acid. (8 to 50 inches thick) |

Type Location: McCreary County, Kentucky; along Rock Creek by gravel road, 2.5 miles southwest of hamlet of Bell Farm, Kentucky.

Range in Characteristics: Solum thickness ranges from 40 to 60 or more inches. Depth to hard rock ranges from 48 inches to more than 120 inches. The argillic portion has clay content of 20 to 35 percent. Coarse fragments are scattered through the soil in an irregular pattern. They vary in size from 3 inches to 15 inches and comprise 5 to 35 percent of the solum and 30 to 70 percent of the C horizon. Reaction of the unlimed soil is strongly or very strongly acid. The Ap horizon is brown or dark brown with hues mainly of 10YR or 7.5YR, values of 4 or 5 and chromas of 2 through 4; it is silt loam or loam, or channery, shaly or stony analogues. The A1 or Ap horizons, 1 to 5 inches thick, have colors ranging from very dark grayish brown (2.5Y 3/2) through brown (10YR 4/3); A2 horizons are grayish brown or pale brown; texture is similar to that of the Ap horizon. The Bt horizons are mostly strong brown, yellowish brown or light olive brown in hues of 7.5YR, 10YR and 2.5Y with values of 4 or 5 and chromas of 4 through 8; texture is silty clay loam or silt loam; usually structure is weak or moderate, medium or coarse subangular blocky; and consistence is firm or friable. The B3 horizon, where present, has enough illuvial clay to qualify as part of the argillic horizon. The C horizon is yellowish brown, grayish brown or light olive brown; texture is channery or very channery with fines of silt loam, silty clay loam, clay loam, silty clay, or loam; structure is massive or weak fine subangular blocky; some pedons have mottles in shades of gray, brown, or red.

Competing Series and Their Differentiae: The Shelocta series is a member of a large family of which the Aura, Bedington, Bucks, Butano, Chester, Elsinboro, Fairfax, Frankstown, Gilpin, Glenelg, Leck Kill, Manassas, Meadowville, Murrill, Nixon, Quakertown, Rayne, Shouns, and Whiteford series have B2t horizons with textures of silt loam or silty clay loam. The Aura, Fairfax, Manassas, Nixon and Shouns soils have 5YR or redder hues in some or all subhorizons of the Bt horizon. In addition, the Aura soils have thicker sola; the Fairfax soils have an upper solum in a silty mantle and a lower solum in residuum from schist and gneiss; the Nixon soils have formed in stratified water-sorted cobbly and gravelly deposits. The Bedington soils have argillic horizons with hues mostly 5YR or redder, otherwise they are close

Shelocta Series

competitors. The Bucks, Elsinboro, Frankstown, Gilpin, Glencelg, Leck Kill, Quakertown and Whiteford soils have thinner sola. In addition, the Bucks soils have argillic horizons with hues mostly 5YR or redder; the Elsinboro soils have lower sola with hues mostly 5YR or redder; the Frankstown and Quakertown soils have thinner argillic horizons; the Gilpin soils are shallower to bedrock; the Glencelg soils typically have 15 percent or more gravel in the solum; the Leck Kill and Whiteford soils have 5YR or redder hues in some or all subhorizons of the Bt horizon. The Chester soils have argillic horizons which extend below 40 inches, some part of which nearly always has hue of 5YR. The Meadowville soils have lower argillic horizon with sandy clay loam or sandy clay textures formed in unconforming materials. The Murrill soils typically contain 15 percent or more channers in the upper solum and have a lower solum formed in unconforming materials. The Rayne soils have argillic horizons 20 to 30 inches thick that terminate 30 to 40 inches below the surface of the soil. The Hayter and Muse series are in related families. The Hayter soils have base saturation of less than 60 percent at a depth of 50 inches below the top of the argillic horizon, and argillic horizons with clay loam, sandy clay loam and loam textures. The Muse soils have 35 percent or more clay by weight in the control section and 5YR hues in the lower part of the argillic horizon.

Setting: Gently sloping to steep upland areas, footslopes and benches. Slopes range from 5 to 60 percent and most are concave. These soils are in areas with 42 to 54 inches average annual precipitation and average annual temperatures range from 48 to 59°F. Shelocta soils have formed in the weathered product of colluvial material from acid shale, siltstone, and sandstone.

Principal Associated Soils: Shelocta is the well drained member of a drainage sequence with Ernest as the moderately drained member and Brinkerton as the somewhat poorly or poorly drained member. Soils in surrounding uplands are the competing Gilpin and the Dekalb, Muskingum, Weikert and Wellston or Whitley series. All of these have solums less than 40 inches thick.

Drainage and Permeability: Well drained, medium to rapid surface runoff, medium internal water movement, and moderate permeability.

Use and Vegetation: About 50 percent of Shelocta soils are cleared and used for general crops and pasture. Wooded areas have mixed hardwoods - oaks, gum, maple, yellow poplar, cucumber, and some pine and hemlock.

Distribution and Extent: The plateau and mountain areas of Kentucky, Maryland, Pennsylvania, Virginia, West Virginia and Tennessee. The series is of large extent.

Series Established: Indiana County, Pennsylvania, 1937.

Remarks: These soils were classified as Gray Brown Podzolic soils in the 1938 classification system.

National Cooperative Soil Survey
USA